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Hazardous Waste Tank Failure (HWTF) and Release Model: Description of Methodology, Appendices A, B, C, D, and E

Pope-Reid Associates, Inc., St. Paul, MN

Prepared for

Environmental Protection Agency, Washington, DC

13 Jan 86

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DRAFT REPORT

HAZARDOUS WASTE TANK FAILURE MODEL: DESCRIPTION OF METHODOLOGY

Prepared for:

U.S. Environmental Protection Agency
Office of Solid Waste
Economic Analysis Branch
January 13, 1986

Submitted by:

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The purpose of this study is to evaluate the frequency and severity of various failure mechanisms for a variety of hazardous waste storage and treatment tank systems. The reusage of hazardous waste from treatment and storage tanks is contingent on the occurrence of one or more failure events, many of which have a degree of uncertainty associated with them. Consequently, this analysis used a model to account for such uncertainties. The HWTF model is based on the principles of probability and statistics and can simulate particular aspects of phenomena that relate to the release of hazardous waste from tanks. This type of model, generally referred to as a Monte Carlo simulation model, allows the evaluation of the potential range of releases from tanks.

KEYWORDS: *Hazardous materials, *Solid waste disposal, *Failure.

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1.0 INTRODUCTION

1.1 Overview

Risks to human health and the environment from the operation of hazardous waste tank facilities may result from air emissions, leaks from tanks and piping, or large spills or overflows. Some losses are relatively constant baseline releases resulting from the facility's design or normal operating practices. Other losses are more sudden and result in short-term high-volume releases of concentrated material. Such releases may result from natural catastrophes or from bursting pipes or ruptured tank seams. High-volume releases are also possible from long-term undiscovered leaks. Such leaks may linger for years at levels just below the detection threshold, releasing thousands of gallons of hazardous waste into the environment.

The cause of release varies from incident to incident, but may include one or more of the following:

- normal operating discharges or air emissions from the facility;
- equipment aging or deterioration from environmental exposure;
- human error in design, construction, installation, or operation;
- system-generated stresses due to incompatibilities between waste constituents and equipment; or
- severe environmental stresses such as fires, floods, storms, or earthquakes.

The purpose of this study is to evaluate the frequency and severity of various failure mechanisms for a variety of hazardous waste treatment and storage tank systems. To accomplish this objective, we used published sources and our own engineering analyses to develop failure scenarios (combinations of events leading to system failure) for each tank system. We evaluated these scenarios using fault tree techniques and a Monte Carlo simulation model to predict the probabilities, magnitudes, and concentrations of releases over a 20-year operating life.

By modelling the reliability of various tank designs, the present study will provide information to help the Agency develop regulations for the management of hazardous waste tanks. The Agency can also apply our predicted release volumes to contaminant transport models and dose-response models in order to estimate human health risks from various tank designs. In addition, the Agency may combine these risk estimates with design and operating cost data to evaluate the cost-effectiveness of various regulatory approaches.

1.2 Methodology

This study involved two basic techniques: fault tree analysis and Monte Carlo simulation.

Fault tree analysis is a common engineering method for evaluating the reliability of complex systems. The first step in such an analysis is to select a "top" or "ultimate" failure event. In the case of hazardous waste tanks, such an ultimate failure involves the release of hazardous waste from the tank system. This top event is then traced backward to identify all relevant intermediate failure events which might lead to it. These events are in turn traced back to their antecedents, and the analysis is continued until no further reduction is possible or no data are available. The resulting chains of causation are the fault trees.

After the fault trees have been designed, the next step in fault tree analysis is to estimate the frequency and timing of each of the basic failure events. To do this, we used a combination of engineering analysis and published tables of average service lives or annual failure rates for various components of a tank system. Such data, however, did not enable us to predict with certainty the date of failure for any particular piece of equipment. There are two reasons for this: (1) many types of failure are intrinsically probabilistic in nature; and (2) many others are not well understood. Therefore, it was necessary for us to assign failure probabilities to most of the events, rather than deterministic dates of failure. Consequently, the frequency and timing of the top event is also stochastic in nature, and its probability distribution is a mathematical function of the initiating event probabilities.

Many of the probabilities used in the model involve external events, such as hurricanes or floods and are time-invariant. Other probabilities, such as operator errors or electronic equipment failures, are also assumed to be time-independent, either because their time variations occur over too short a cycle to be of interest to the model, or because the nature of their time-dependencies is unknown. In some cases, however, the probability of component failure may increase with time due to such factors as material aging or accumulated environmental stresses. These failure event probabilities may show complex time-dependencies.

The fault trees developed for this study will be described in detail in Chapter 3. These fault trees model a number of mechanisms by which tank releases can occur. These mechanisms include:

- Overflow
- Leaks and ruptures
- Natural catastrophes
- Releases from secondary containment
- Human error

We evaluated these fault trees by using a computerized Monte Carlo simulation model. During each of the modeled time periods this computer model determines the occurrence of each of the basic failure events by drawing a random number. Using the fault trees, the computer then determines whether the combination of basic failure events which has occurred is sufficient to cause a release. If a release results, the computer calculates the volume of hazardous material that escapes to the environment by first determining the size of the hole (often this involves the selection of one or more additional random numbers), and then calculating the leak rate appropriate for the hole's size and location. The model then determines the time lag until the leak is detected, either by visual inspection, inventory shortfall, or other more sophisticated techniques. Multiplying this time lag by the leak rate gives the total loss volume. Under no circumstances, however, is the leak volume allowed to exceed the sum of the tank's initial contents plus additional deliveries during the detection period.

The model then replaces any tank components whose failure is detected, increments the ages of all surviving components by one time period, and repeats the simulation process. As a result, it generates a time series of releases from the modeled tank. This entire process is repeated hundreds of times, producing a new time profile for each iteration in order to estimate expected failures. The result is as though several hundred tank facilities of similar design were being evaluated for their performance. The resulting distribution of release profiles can be used to determine average, median, and extreme cases. In addition, types, dates, and frequencies of failure can be compiled, as well as expected release volumes and their standard deviations.

1.3 Report Outline

The remainder of this report will discuss in detail the methodology of the hazardous waste tank failure model. The results will be presented in a separate report.

Chapter 2 of this report gives background information about existing hazardous waste tanks. We used this information to determine what types of facilities to model and what types of failure scenarios to include in the fault trees. Chapters 3 and 4 describe the fault trees and the Monte Carlo simulation model, respectively. Chapter 5 concludes the main body of the report by discussing the model's limitations and proposing modifications that might increase its range of applicability.

In addition, this report contains five appendices. Appendix A details the derivation of the probabilities and release volumes used for the fault tree events. Appendix B contains a statistical analysis of a survey of 300 service station tanks, while Appendix C presents case study data on 57 hazardous waste tank failures. Appendix D gives technical specifications for the modeled components and tank systems, and Appendix E lists the computer code for the Monte Carlo model. These appendices will be more thoroughly described in subsequent sections of this report.

2.0 PRELIMINARY ANALYSES

2.1 Introduction

Before designing the fault trees, we conducted several preliminary studies to determine what elements should be built into our fault trees and our Monte Carlo model. These studies included:

- A determination of the design characteristics of existing hazardous waste tanks;
- An analysis of the processes for which these tanks are used;
- A review of the relevant regulations to determine what leak prevention and detection techniques are of the greatest interest to EPA; and
- A review of the relevant technical literature to determine the types of failures to be incorporated into the fault trees.

2.2 Design Characteristics of Existing Hazardous Waste Tanks

Hazardous waste tanks fall into four basic categories: storage tanks, treatment tanks, accumulation tanks, and small quantity generator tanks. Based on the Office of Solid Waste's RIA Tank Survey and the Small Quantity Generator Survey, we subdivided each of these categories according to tank construction material, whether the tanks are above-, below-, or in-ground, and whether the tanks have open or closed tops. As a result, we identified 21 basic types of tank systems. These systems are listed in Table 1, along with their median ages and median capacities. Within each of these categories, however, system age and tank capacities showed considerable variation. Tank ages and capacities are treated as variables in the model. However, for the sake of simplicity, we have assigned fixed values for these parameters in this study.

Not all of the tank systems characterized in Table 1 were specifically identified by the two surveys. Waste accumulation tanks, for example, were not distinguished from storage tanks. Since the only technical difference between storage and accumulation tanks is the length of time between pump-

TABLE 1: CLASSIFICATION AND CHARACTERIZATION OF EXISTING HAZARDOUS WASTE TANKS

Tank Function	Design Configuration	Construction Material	Median Age (yrs)	Median Capacity (gallons)
Treatment	Closed top, above-ground, cradled	Carbon steel	5	2,300
	Open top, above-ground, cradled	Carbon steel	5	2,300
	Open top, above-ground, on-grade	Carbon steel	9	60,000
	Open top, in-ground	Concrete	10	3,700
	Open top, in-ground	Stainless steel	10	3,700
Storage	Closed, above-ground, cradled	Carbon steel	6	5,500
	Closed, above-ground, on-grade	Carbon steel	7	210,000
	Below-ground	Carbon steel	7	4,000
	Below-ground	Fiberglass	7	4,000
	Below-ground	Stainless steel	7	4,000
	In-ground, open	Concrete	8	2,100
	In-ground, open	Carbon steel	8	2,100
Small Quantity Generators	Above-ground, closed	Carbon steel	6	200
	Below-ground	Carbon steel	7	200

TABLE 1. CLASSIFICATION AND CHARACTERIZATION OF EXISTING HAZARDOUS WASTE TANKS (Cont.)

Tank Function	Design Configuration	Material of Construction	Median age(yrs)	Median size (gallon)
Accumulation	Above-ground, cradled, closed	Carbon steel	6	5,500
	Above-ground, on-grade, closed	Carbon steel	21	210,000
	Below-ground	Carbon steel	7	4,000
	Below-ground	Fiberglass	7	4,000
	Below-ground	Stainless steel	7	4,000
	In-ground	Concrete	8	2,100
	In-ground	Carbon steel	8	2,100

outs, we assumed that the storage tank data could also be applied to accumulation tanks. Similarly, since the Small Quantity Generator Survey provides no information on tank construction materials or design capacity, we made the following simplifying assumptions. Since carbon steel is the most common construction material revealed by the RIA survey, we assumed that this material is also used for Small Quantity Generator tanks. We estimated the design capacities of these tanks from through-put information provided by the Small Quantity Generator survey.

The tank systems identified in Table 1 as "Treatment Tanks" are actually used for a wide range of treatment processes. The most common of these processes are listed in Tables 2 and 3 by design capacity and by number of tanks, respectively. We selected six of these processes to model, including distillation, neutralization, cyanide oxidation, chrome reduction, evaporation, and precipitation. In general, we selected the most common processes, but we changed some of the categories used in Tables 2 and 3. Thus, we have combined precipitation, clarification, and sedimentation into a single process which we will label as "precipitation." In addition, because they are similar to short-term storage, we have eliminated blending and decanting from further consideration. (Blending is merely a method of combining wastes for later treatment or storage; decanting is merely a method for separating unlike wastes.)

2.3 Storage and Treatment Processes

In order to provide a visual representation of the processes for which hazardous waste tanks are used, we have developed flow diagrams for storage tanks and for each of the six selected treatment processes. These flow diagrams are presented in Figures 1 through 7. The symbols used in these diagrams are explained in Figure 8. The flow diagrams are somewhat simplified, but they help to illustrate the major components involved in the modeled tank systems. We used these diagrams to develop the framework for our computer model and to identify the effects of specific equipment failures for each of the modeled tank systems. Based on these diagrams, the computer model tracks the hazardous wastes as they pass through different stages of the tank system, checking for component failures at each location where a release might occur.

TABLE 2. 15 MOST COMMON TREATMENT PROCESSES BY TOTAL CAPACITY

Treatment Process or Combination of Processes	Sum of Design Capacities (Gallons)	% of Total Capacity	Number of Tanks
* Decanting	9,930,478	16.6	57
Clarification, Flocculation, Flotation	7,020,000	11.7	3
Clarification, Flotation	5,901,500	9.9	3
* Chemical Precipitation, Neutralization	4,940,320	8.3	26
Activated Sludge	3,138,000	5.2	5
* Clarification	2,843,927	4.8	22
* Neutralization	2,742,940	4.6	124
Clarification, Flocculation	2,450,000	4.1	3
Chlorination, Neutralization	1,501,200	2.5	4
* Sedimentation	1,562,154	2.6	16
Flotation, Sedimentation	1,347,228	2.3	10
Thickening	1,161,674	1.9	10
* Decanting, Filtration, Sedimentation	1,100,490	1.8	15
Flotation, Sedimentation, Evaporation, Aerobic Tank	880,000	1.5	2
Chemical, Reduction, Flocculation, Flotation	750,000	1.3	3
All other technologies	12,523,459	20.9	571
Total	59,793,370	100%	874

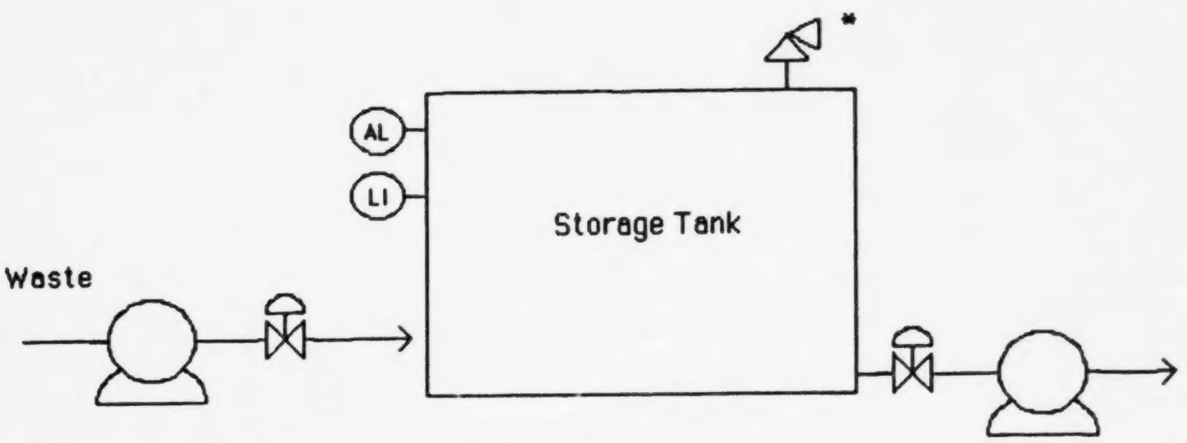
* This process is also included in Table 3 (most common treatment processes by number of tanks).

TABLE 3. 15 MOST COMMON TREATMENT PROCESSES BY NUMBER OF TANKS

Treatment Processes or Combination of Process	Number of Tanks	% of Total Number of Tanks	Sum of Designs Capacities (Gallons
* Neutralization	124	14.2	2,742,840
* Decanting	57	6.5	9,930,478
Chemical Reduction	48	5.5	113,549
Chemical Oxidation	44	5.0	204,409
Blending	31	3.5	512,375
* Chemical Precipitation, Neutralization	26	3.0	4,940,320
Chemical Reduction, Degradation	24	2.7	20,640
Chemical Precipitation	23	2.6	226,001
Cyanide Destruction	23	2.6	92,016
* Clarification	22	2.5	2,843,927
Sedimentation, Blending	18	2.1	385,425
* Sedimentation	16	1.8	1,562,154
Evaporation	16	1.8	21,115
* Decanting, Filtration, Sedimentation	15	1.7	1,100,490
Chemical Reduction, Neutralization	11	1.3	87,700
All other technologies	376	43.0	35,009,931
Total	874	100%	59,793,370

* This process is also included in Table 2 (most common treatment processes by total capacity).

FIGURE 1. STORAGE

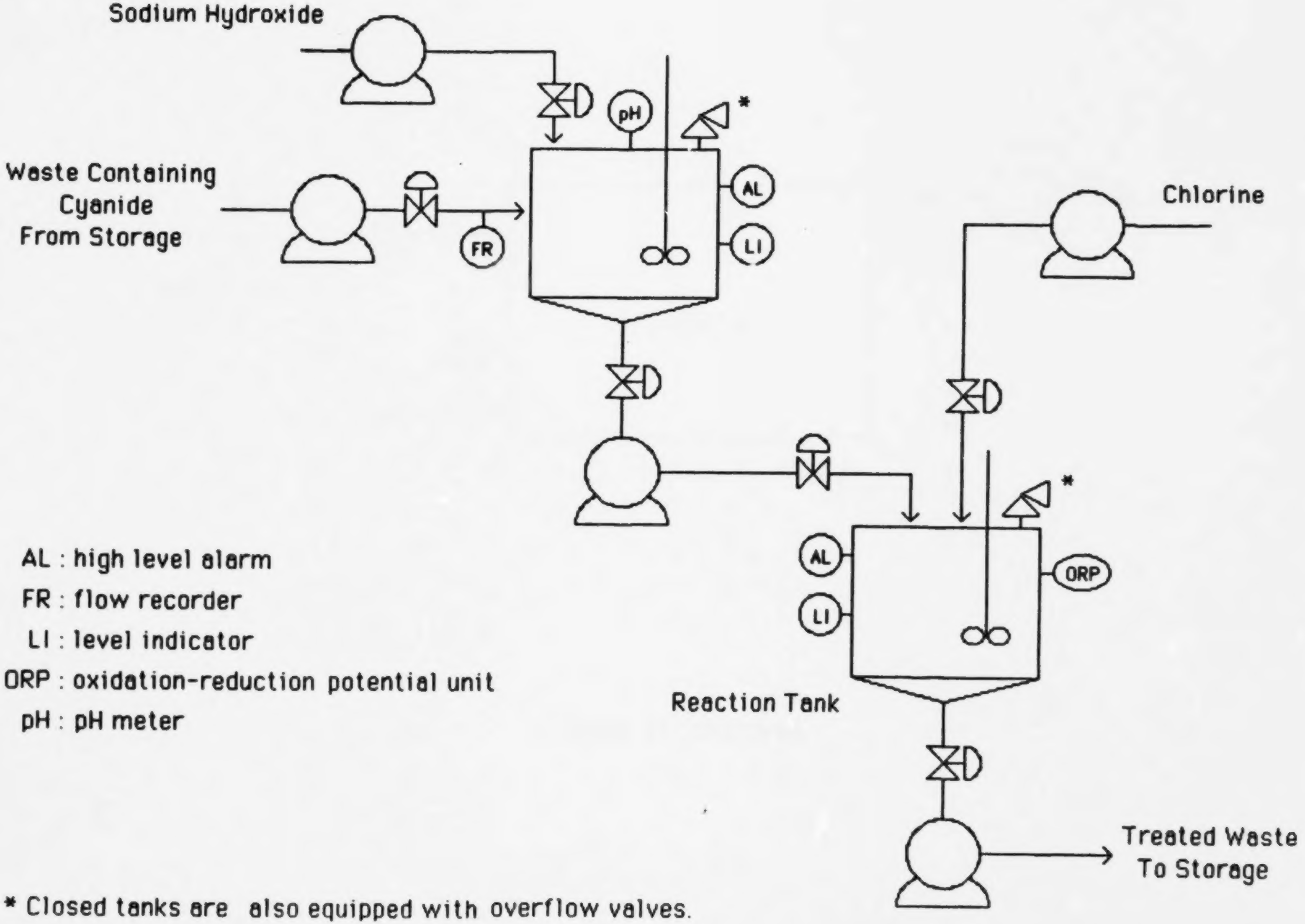

*
AL
LI
Storage Tank
Waste

AL: high level alarm

LI: liquid level indicator

* Closed tank is also equipped with an overflow valve.

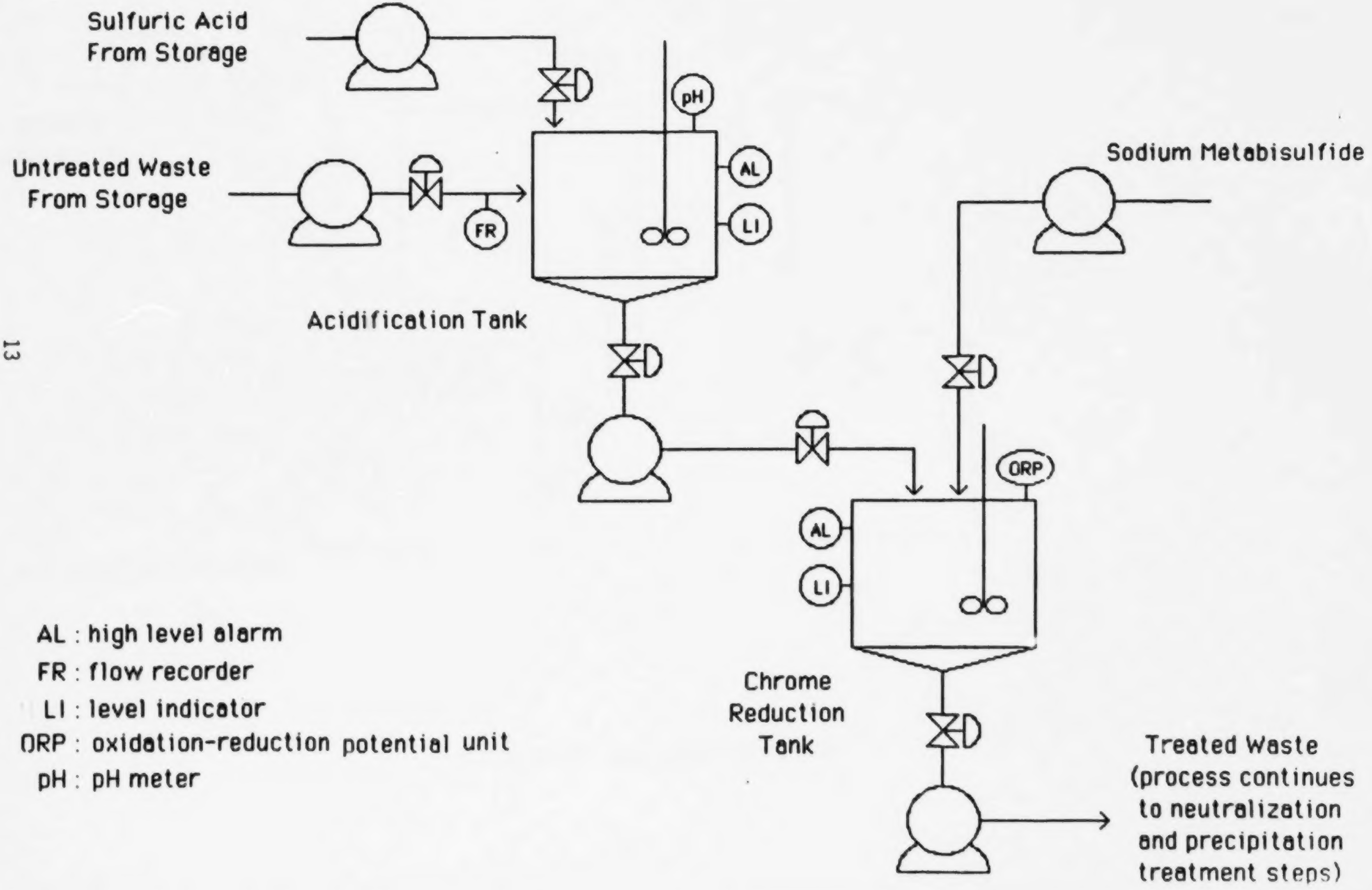
FIGURE 2. CYANIDE OXIDATION


Sodium Hydroxide
Waste Containing Cyanide From Storage
pH
AL
LI
FR
*
Chlorine
AL
LI
ORP
Reaction Tank
Treated Waste To Storage

AL : high level alarm
FR : flow recorder
LI : level indicator
ORP : oxidation-reduction potential unit
pH : pH meter

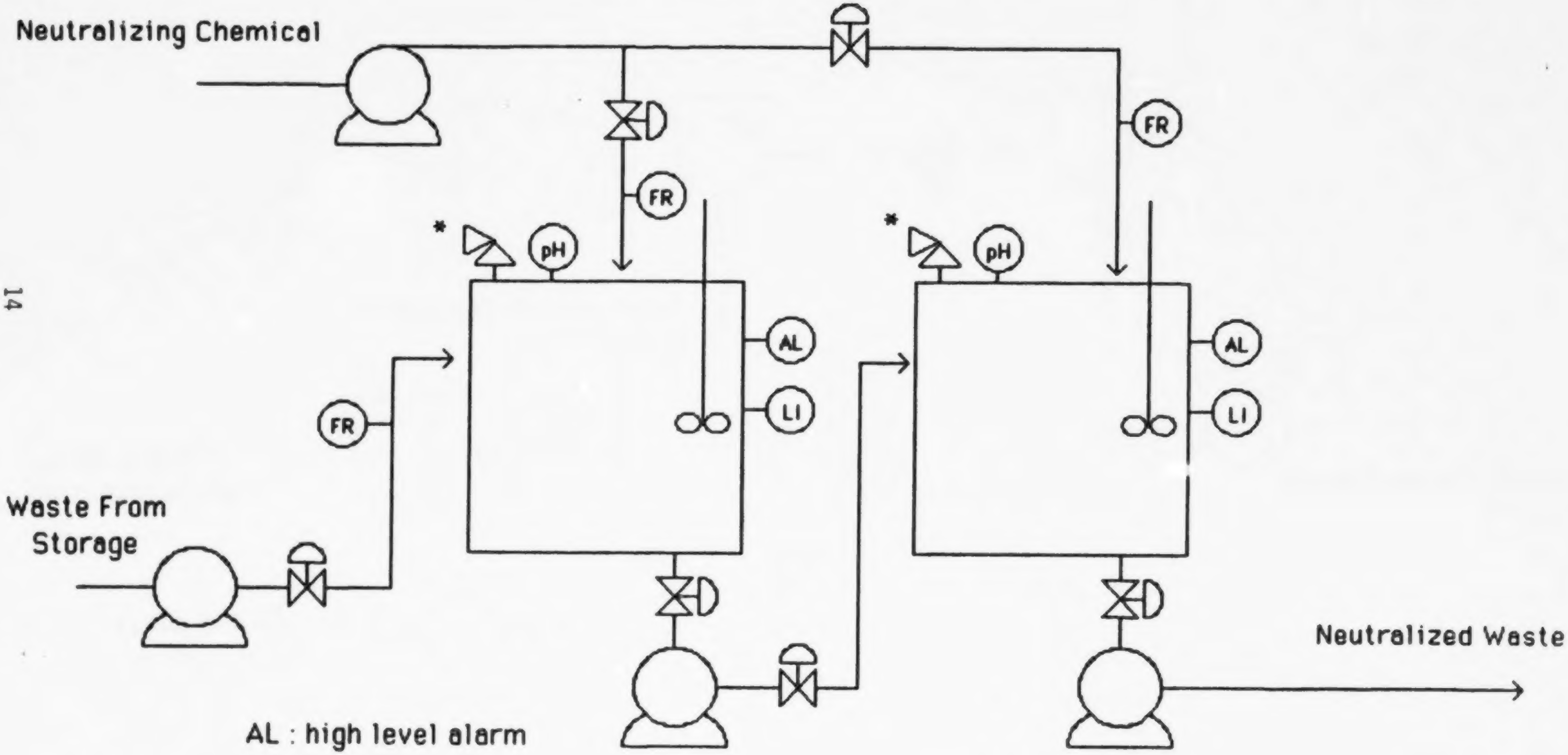
* Closed tanks are also equipped with overflow valves.

FIGURE 3. CHROME REDUCTION


Sulfuric Acid
From Storage
Untreated Waste
From Storage
pH
AL
LI
FR
Acidification Tank
Sodium Metabisulfide
ORP
AL
LI
Chrome
Reduction
Tank
Treated Waste
(process continues
to neutralization
and precipitation
treatment steps)

AL : high level alarm
FR : flow recorder
LI : level indicator
ORP : oxidation-reduction potential unit
pH : pH meter

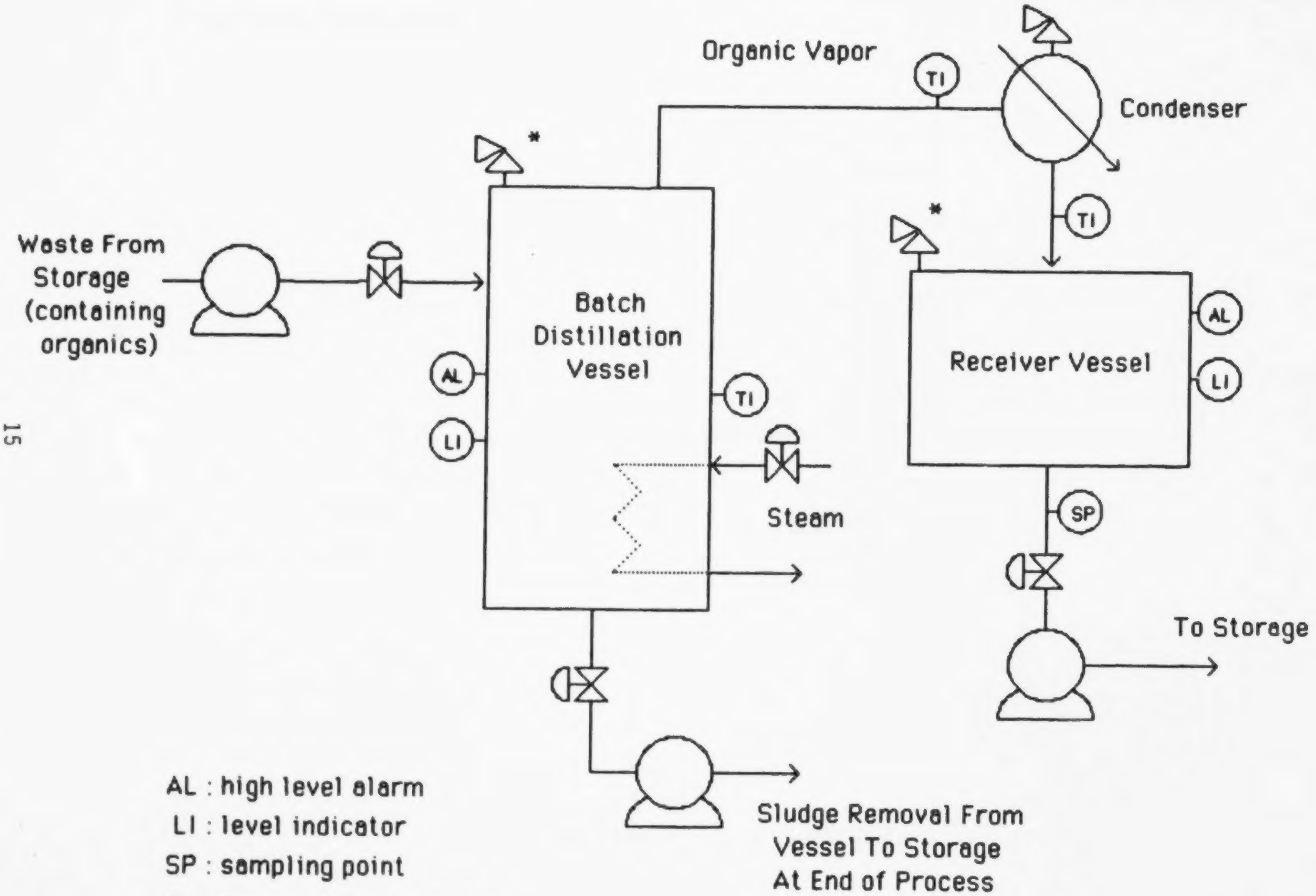
FIGURE 4. NEUTRALIZATION


Neutralizing Chemical
FR
FR
FR
*
pH
*
pH
AL
LI
AL
LI
Waste From Storage
Neutralized Waste

AL : high level alarm
FR : flow recorder
LI : level indicator
pH : pH meter

* Closed tanks are also equipped with overflow valves.

FIGURE 5. DISTILLATION


Organic Vapor
TI
Condenser
*
Waste From Storage (containing organics)
Batch Distillation Vessel
AL
LI
TI
Steam
TI
*
Receiver Vessel
AL
LI
SP
To Storage
Sludge Removal From Vessel To Storage At End of Process

AL : high level alarm
LI : level indicator
SP : sampling point
TI : temperature indicator

* Closed tank is also equipped with an overflow valve.

FIGURE 6. EVAPORATION

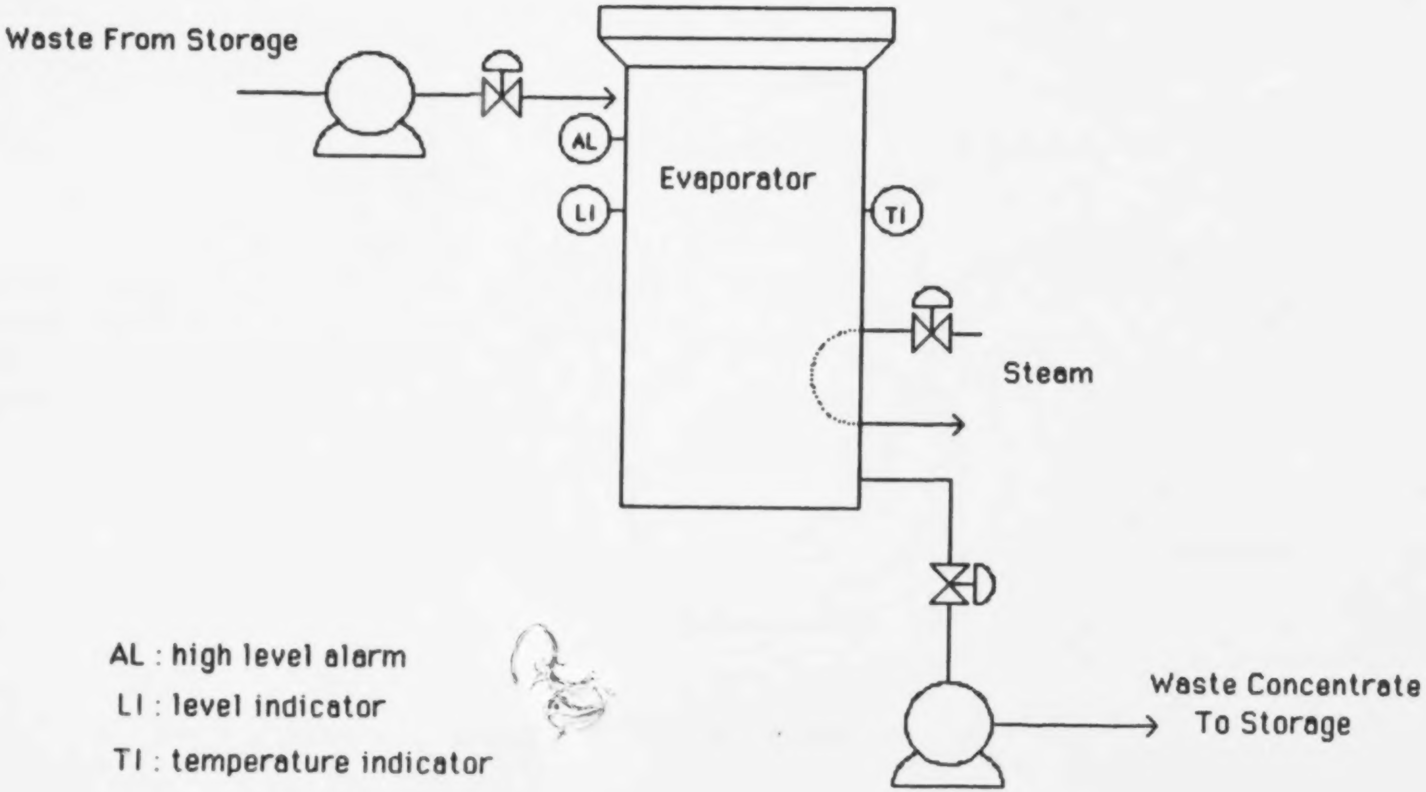

Waste From Storage
AL
LI
Evaporator
TI
Steam
Waste Concentrate
To Storage
AL : high level alarm
LI : level indicator
TI : temperature indicator

FIGURE 7. PRECIPITATION

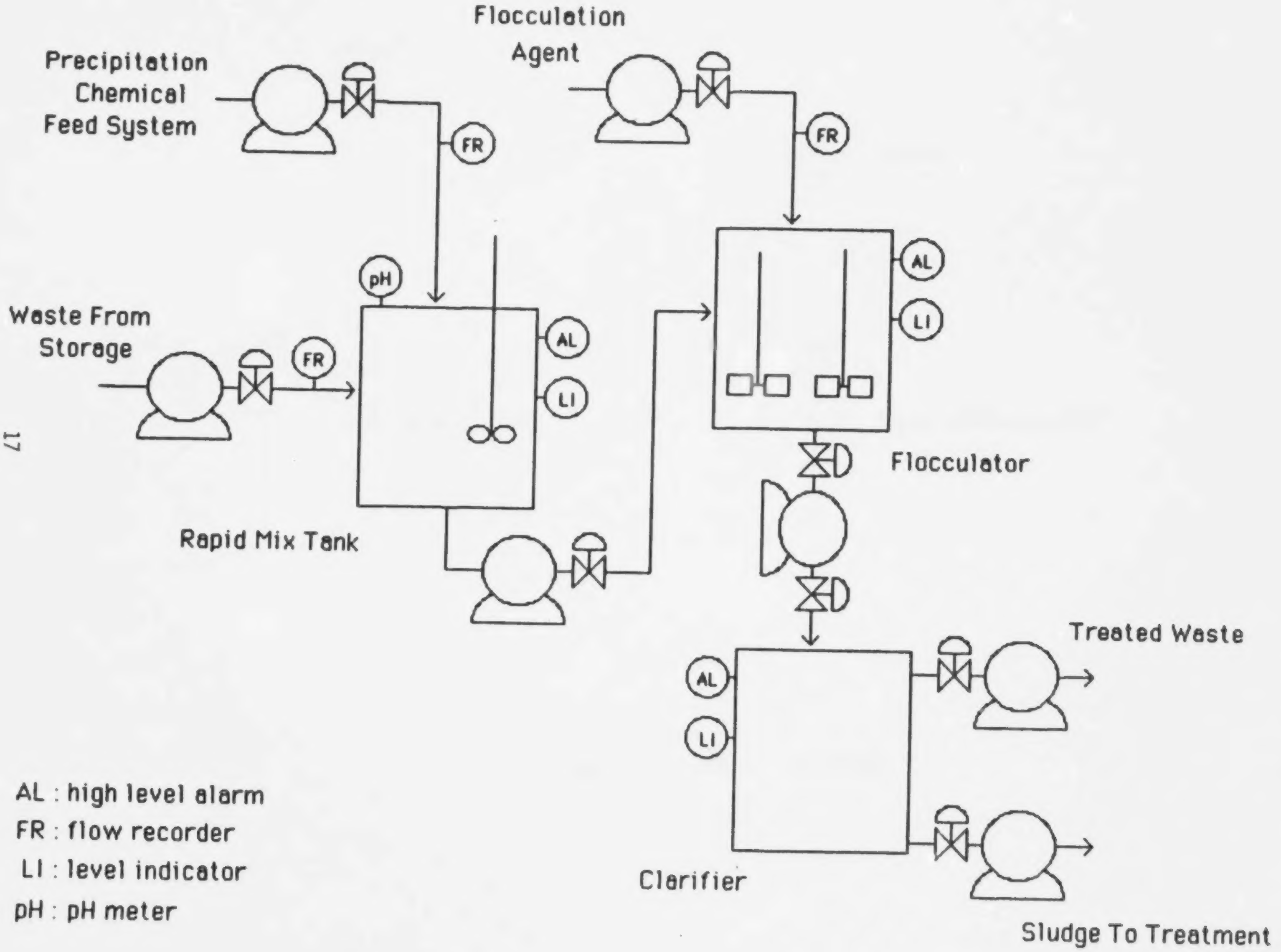
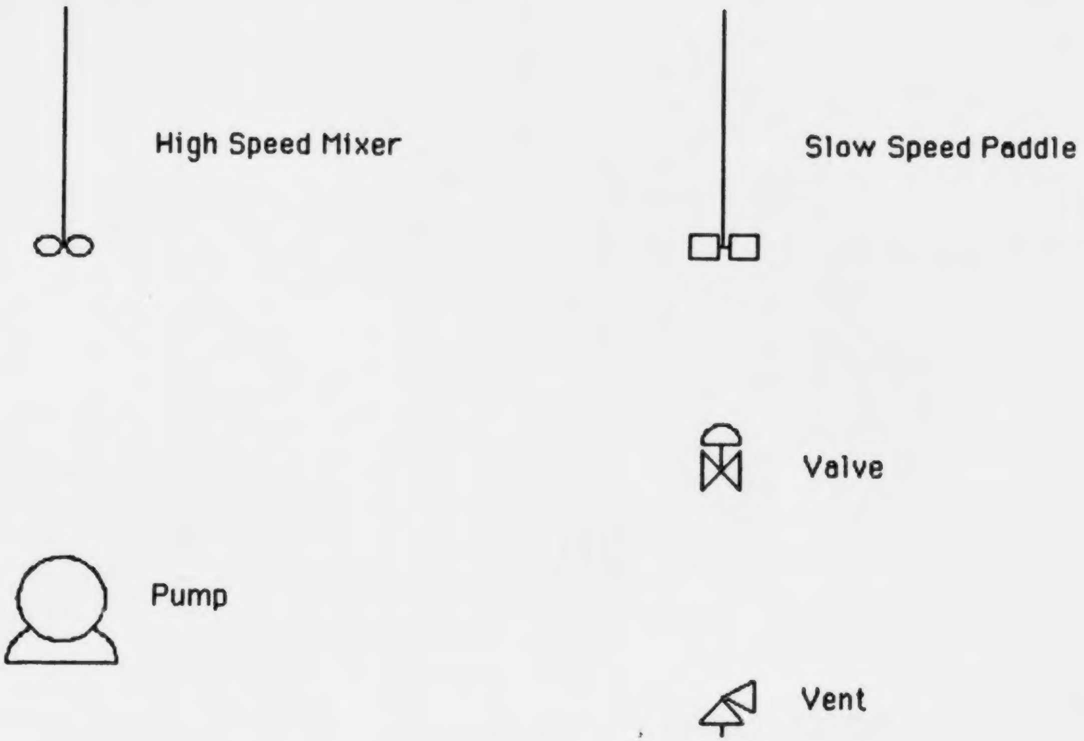

Flocculation Agent
Precipitation Chemical Feed System
FR
FR
pH
Waste From Storage
FR
AL
LI
AL
LI
Flocculator
Rapid Mix Tank
Treated Waste
AL
LI
Clarifier
Sludge To Treatment
AL : high level alarm
FR : flow recorder
LI : level indicator
pH : pH meter

FIGURE 8. SYMBOL LEGEND


High Speed Mixer
Slow Speed Paddle
Valve
Pump
Vent

Storage and Accumulation Tanks

These tanks (Figure 1) are the simplest tank systems. EPA defines storage tanks as tanks that store wastes for greater than 90 days, while accumulation tanks are those that store wastes for less than 90 days. A storage tank may continuously contain some waste, but an accumulation tank must be completely emptied at least every 90 days.

Storage and accumulation tanks consist of three basic elements: a fill and discharge system (either using pumps or gravity-feed), piping, and the tank itself. The tank may be above-ground, in-ground, or below-ground and may vary in size and material of construction, (see Table 1). The pipes may be above-ground or below-ground, and the fill/discharge system may include such features as liquid-level indicators, high-level alarms, or automatic shut-off controls.

Treatment Tanks

Treatment tanks differ from storage and accumulation tanks by having additional equipment and by requiring more attention during process operations when chemicals are mixed or added. The six selected treatment processes are diagramed in Figures 2 through 7. The following discussions present brief explanations of each of these diagrams.

Cyanide Oxidation, Chrome Reduction, and Neutralization. These processes are diagramed in Figures 2 through 4, respectively. These treatment technologies can be discussed together because all three involve chemical processes designed to render the waste less hazardous. The flow diagrams are therefore similar, with each treatment process involving a two-stage tank system as well as the storage tanks generally used for both untreated and treated wastes.

The first of these processes, cyanide oxidation, involves the oxidation of free cyanide to carbon and nitrogen. (Destruction of free cyanide to cyanates is also possible; we did not model this process, however, because cyanates are still somewhat toxic and may in some cases require further treatment). Several oxidizing agents are possible, but in this model we assume chlorine is used. For this process, an alkaline environment (pH of at least 8.5) is required to prevent the formation of an extremely toxic gas, cyanogen chloride.

As is shown in Figure 2, the pH adjustment and the addition of chlorine occur as two distinct phases of treatment. In the first phase, the pH is adjusted to the desired level; in the second phase chlorine is added to the waste and allowed to react for 90 minutes. The treatment efficiency approaches 100 percent, but rather than specifying any given percentage, we have left this variable as an input parameter for the model.

In a cyanide oxidation facility, the first tank can be open or closed, but a vent and an overflow valve must be added if the tank is closed. A mixer blends the pH-adjusting chemical (generally sodium hydroxide) with the hazardous waste, and a pH meter monitors the results. Other tank accessories include a level indicator and a high-level alarm. The second tank is always closed because of the possibility of cyanogen chloride formation if the pH has been improperly controlled. Like the first tank, this tank has a vent, an overflow valve, a mixer, a level indicator, and a high-level alarm. An ORP (oxidation-reduction potential) meter is also used to determine when the chlorine has fully reacted with the cyanide.

Chrome reduction (Figure 5) is similar to cyanide oxidation. As with cyanide oxidation, the pH must first be adjusted, this time by adding sulfuric acid until the pH is between 2 and 3. The reduction of chromium (VI) to the less toxic chromium (III) is then carried out in the second tank by the addition of sodium metabisulfite. The resulting chromium (III) can later be precipitated out of the waste stream.

Both the pH adjustment tank and the reaction tank can be open or closed, and each has the same features as the equivalent cyanide oxidation tank, including mixers, level indicators, high-level alarms, a pH meter on tank 1, and an ORP meter on tank 2.

Neutralization alone is not regulated as a hazardous waste treatment technology. It is modeled in this study, however, because neutralization must be used to treat the highly acidic products of the chrome reduction process. Neutralization is therefore a necessary adjunct to this treatment process.

A neutralization process is a two-stage procedure for adding a dilute solution of an acid or a base to move the waste's acidity into the range of pH 6 to 8. Half of the necessary neutralizing agent is added in each stage of the process, and the mixture is allowed to react for thirty minutes. Both tanks in the neutralization process are equipped with mixers, pH meters, high-level alarms, level indicators, and overflow valves (if the tanks are closed).

Evaporation, Distillation, and Precipitation. We can also discuss distillation, evaporation, and precipitation together because these three treatment technologies all involve the concentration of the hazardous constituents for recovery or further treatment. The flow diagrams for these processes are presented in Figures 5 through 7.

Evaporation and distillation are very similar treatment methods. Both use a heat source to volatilize and separate a portion of the waste. In evaporation, the solvent (usually water) is evaporated, leaving the concentrated hazardous waste in the evaporator. In some cases the evaporator is an open, outdoor tank using solar energy to evaporate the solvent.

Distillation also involves volatilization, but in this process the volatilized fractions are the hazardous materials, which must therefore be collected for subsequent treatment or disposal. Sometimes, multiple distillations may be used to separate and recover the various hazardous constituents.

Precipitation is the most complex of the three "concentration" processes. In the first step of this process, sodium hydroxide is added to the waste to alter the pH to the level appropriate for the particular waste being treated. The waste is then vigorously agitated and passed to a flocculating tank, where a flocculating agent is added to agglomerate the solids. Slow mixing is used at this stage to assure adequate contacting without breaking up the flocs that have developed. From the flocculating tanks the waste flows into a clarifier. Here, the solids settle to the bottom and are removed as a sludge. The clarified liquid is the treated waste. Thus, precipitation involves three tanks, all of which are equipped with level indicators and high level alarms; the first two tanks also have mixers.

2.4 EPA's Proposed Hazardous Waste Tank Regulations

EPA has recently proposed revised regulations for hazardous waste tanks. These regulations would apply to existing tank facilities seeking permits, new tank facilities, and existing tanks operating under interim status. Slightly different requirements would apply to each of these types of facilities.

The proposed permitting standards for existing tanks include the following features:

- The tank system's structural integrity would have to be assessed by a qualified engineer.
- For metal tanks, this assessment would have to include a determination of the type and degree of corrosion protection needed to ensure the integrity of the system for its intended life. (This requirement would replace the minimum shell thickness requirements currently in force).
- The facility would be required to either install full secondary containment or implement a groundwater monitoring program.
- Facilities that elect to use a groundwater monitoring program instead of full secondary containment would still be required to install partial secondary containment for any above-ground portions of their systems. In addition, such facilities would also need to test the integrity of their underground components every six months.
- Facilities that have secondary containment would be required to maintain leak detection systems capable of detecting leaks within 24 hours.
- All tanks subject to the 90-day accumulation provisions of 40 C.F.R. §262.34 would be required to have full secondary containment.

The proposed permitting requirements for new tank systems address similar concerns, as do the proposed regulations applying to tanks under interim status. The primary differences between the regulations for new tanks and those for existing tanks are that new tank systems would have no alternative to the installation of secondary containment, would be required to install corrosion protection, and would be required to obtain expert certification of proper installation. Facilities with interim status would be required to meet requirements similar to those applicable to existing facilities seeking permits, except that interim status facilities would be given six months to implement the necessary changes.

In order to assure the effectiveness of these permitting standards, EPA proposes to revise the inspection regulations to require that structures or devices required under the new regulations, such as corrosion protection devices and leak detection systems, be periodically inspected. In addition, these revisions would require owners and operators to establish schedules for assessing the integrity of above-ground and in-ground tanks and to establish procedures for responding to leaks once they are detected.

As the preceding discussion indicates, the proposed regulations incorporate a number of technological features. These features include:

- partial secondary containment,
- full secondary containment,
- groundwater monitoring,
- corrosion protection,
- periodic visual inspections,
- leak testing, and
- leak detection.

The purpose of our Tank Failure Model is to evaluate the effectiveness of these options, either alone or in combination. Although it is possible to include all of these features in a single simulation model, the groundwater monitoring options have not been directly included in our model. Because groundwater monitoring does not affect tank failure probabilities or frequencies the Hazardous Waste Tank Failure Model does not simulate these scenarios. Instead, the Agency will examine how these regularory options influence riask using the Hazardous Waste Tank Risk Model.

2.5 Tank Failure Mechanisms

In addition to reviewing EPA's proposed tank regulations, we also reviewed the relevant technical literature for information on system and component reliabilities and failure modes. This review focused on the causes, consequences, and probabilities of failure, as well as on the magnitude of release once failure occurs.

Our literature search used the following sources and data bases:

- PRA's in-house library;
- University of Minnesota libraries;
- COMPENDEX (computer search);
- National Technical Information Service (computer search); and
- Pollution Abstracts (computer search).

Based on both a manual search of more recent periodicals and the computer searches, we obtained, reviewed, and abstracted those articles that we deemed pertinent to this study. The Bibliography to this report lists these sources. The PRA report titled "The Analysis of Component Failures of Hazardous Waste Storage and Treatment Systems: Annotated Bibliography," (Draft, July 1984), contains the abstracts.

We also reviewed and abstracted case studies of particular failure incidents. In reviewing these case studies, we were primarily interested in determining the following:

- a description of the incident;
- the cause of the release;
- the identity of the released materials;
- the duration of the incident;
- tank design and operating characteristics;
- environmental conditions; and
- the geologic characteristics of the subgrade materials.

Appendix C summarizes these case studies.

Using these case studies and our general literature review, we developed a classification of the various mechanisms that could cause tank system failures. We identified five general categories of failure mechanisms:

- stresses due to the tank's external environment;
- stresses arising from the tank's internal environment;
- design flaws;
- construction and installation errors; and
- operation or maintenance errors.

Once we had identified these mechanisms, we used vendor information and engineering handbooks to determine the specific ways in which each mechanism could contribute to the failure of various tank components. The results of this analysis are presented in matrix form in Tables 4 through 6.

Table 4 tabulates the possible effects of external environmental stresses. The vertical axis lists the types of stresses which may occur, while the horizontal axis indicates which components are vulnerable to each type of stress. The table also identifies the process by which each of these external stresses may lead to component failure.

This table indicates that external environmental factors contributing to failure include temperature extremes, high winds, excessive rainfall, adverse soil conditions, earthquakes, poor air quality, power failures, and vandalism. These stresses may result in corrosion, rupture, spills, or overflows. The affected components may include tanks, pipes, pumps, valves, level indicators, or process control equipment such as automatic level controllers, overflow alarms, or emergency shut-off systems. Each type of external stress, however, does not affect all components. Thus, adverse soil characteristics only affect below-ground pipes or in- or below-ground tanks, and power failures only affect pumps, valves, level indicators and process control equipment. Some events, such as earthquakes, could affect any component. Since these events would affect the entire tank system simultaneously, however, the damage to the pipes and ancillary equipment would be unimportant compared to the damage to the tank itself. Therefore, for such catastrophic events, Table 4 only lists damage to the tank and ignores the incidental effects on other components.

Table 4. TANK SYSTEM FAILURE MATRIX: EXTERNAL ENVIRONMENTAL STRESSES

		AFFECTED COMPONENTS										
FACTORS CONTRIBUTING TO FAILURE	TYPE OF FAILURE	Above-ground tanks	In-ground tanks	Below-ground tanks	Pumps	Valves	Above-ground piping	Below-ground Piping	Welded Flanges	Gaskets	Level indicators	Process control equipmen
power failure	overflow				*	*					*	*
temperature extremes	explosion; cracking	*	*	*								
high winds/storms	rupture; spills; over-turning	*	*									
humidity extremes	corrosion	*	*		*		*					
floods	overflow; overturning	*	*	*								
adverse soil characteristics	corrosion		*	*				*	*			
earthquakes	rupture; overturning; spills	*	*	*								
adverse air quality	corrosion	*	*		*		*					
vandalism/unauthorized entry	rupture; overflow; fire	*	*	*								
other catastrophic event	rupture	*	*	*								

---

* Signifies an effect upon the particular component or upon its operation.

Table 5. TANK SYSTEM FAILURE MATRIX: INTERNAL ENVIRONMENTAL STRESSES

		AFFECTED COMPONENTS										
FACTORS CONTRIBUTING TO FAILURE	TYPE OF FAILURE	Above-ground tanks	In-ground tanks	Below-ground tanks	Pumps	Valves	Above-ground piping	Below-ground Piping	Welded Flanges	Gaskets	Level indicators	Process Control Equipment
equipment aging	equipment failure or malfunction: corrosion; rupture	*	*	*	*	*	*	*	*	*	*	*
pH extremes	corrosion	*	*	*	*	*	*	*	*	*	*	
excess amounts of suspended solids	abrasion;				*	*	*	*	*	*		
ignition of waste	explosion, rupture, loss of system contents	*	*	*	*	*	*	*				
temperature extremes	corrosion	*	*	*	*	*	*	*	*	*		
pressure extremes	rupture or collapse	*	*	*	*	*	*	*				

---

* Signifies an effect upon the particular component or upon its operation.

Table 6. TANK SYSTEM FAILURE MATRIX: DESIGN, CONSTRUCTION, AND OPERATION ERRORS

		AFFECTED COMPONENTS										
FACTORS CONTRIBUTING TO FAILURE	TYPE OF FAILURE	Above-ground tanks	In-ground tanks	Below-ground tanks	Pumps	Valves	Above-ground piping	Below-ground Piping	Welded Flanges	Gaskets	Level indicators	Process Control Equipment
DESIGN												
poor material selection	collapse or rupture; corrosion	*	*	*	*		*	*	*	*		
poor component selection	accelerated component aging				*	*			*	*	*	*
inadequate structural support	overturning; collapse; rupture	*	*	*	*		*	*	*			
CONSTRUCTION/INSTALLATION												
damage during installation	cracks; scrapes; dents	*	*	*	*	*	*	*	*	*	*	*
improper materials used	corrosion; rupture or collapse	*	*	*	*	*	*	*		*		
improper component installed	accelerated component aging due to excessive stress				*	*					*	*
poor subgrade preparation	settling; cracking; rupture; corrosion	*	*	*			*	*	*			
OPERATION/MAINTENANCE												
operator fails to control process	overflow; internal environmental extremes; failure to detect on-going release	*	*	*								
operator deliberately ignores safety or control measures	overflow; internal environmental extremes; failure to detect on-going release	*	*	*								
improper cleaning, inspection, observation, record-keeping, or replacement	equipment malfunction/ failure; failure to detect on-going release	*	*	*	*	*	*	*	*	*	*	*

---

* Signifies an effect upon the particular component or upon its operation.

Table 5 itemizes internal environmental stresses, including extremes of temperature, pressure, and pH, and variations in the amount of suspended solids. We have also included equipment aging in this category. These internal factors may result in accelerated corrosion, equipment overload, overflows, or equipment malfunctions. The specific components affected by each factor are identified in the table.

Two of these factors, temperature extremes and pressure extremes, are important stresses for many classes of industrial tanks, but are not particularly important for hazardous waste tanks because these tanks are seldom operated at high temperatures or pressures. For completeness, we have included these factors in Table 5, but we will not give them special status in our model.

Table 6 examines design, construction, and operation errors. Such errors include poor material selection, use of improper components, inadequate structural support, improper process design, installation damage, use of improper materials or components, operator error, or improper maintenance. These errors may cause structural collapse, rupture, accelerated corrosion, equipment malfunction, inadequate capacity, improper process control, or failure to detect on-going releases. The specific components vulnerable to each of these failures are identified in the table.

3.0 FAULT TREES

3.1 Introduction to Fault Tree Analysis

Fault tree analysis is a common engineering tool for evaluating the reliability of complex systems. The first step in such an analysis is to identify the "top" or "ultimate" failure event to be modeled. In the present study, the ultimate failure event is the release of hazardous materials from the tank system. To construct our fault trees, we then identified all of the relevant intermediate failure events which might lead to such a failure. We then traced these events back to their antecedents, continuing the analysis until no further reduction was possible or no data were available. The resulting chains of causation are the heart of our fault trees.

In many cases, we found it useful to simplify the fault trees by combining similar events and by eliminating very low-probability events or events whose occurrence may always be assumed. Examples of these last two types of events are the probability of a meteor strike or the presence of oxygen to support an outdoor fire, respectively. In general, we have pruned events with probabilities less than 10^{-5}, though in a few cases we have retained them in order to show that they were indeed considered.

Fault trees are generally depicted by a standardized set of schematic symbols which represent the linkages between the basic, intermediate, and top events. There are two principal types of fault tree symbols: event symbols and logic gates. Event symbols are used to distinguish various types of events, as well as to illustrate the connections among the different portions of a large fault tree. The event symbols which will be used in this report are illustrated in Figure 9.

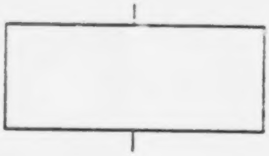
Logic gates are used to link higher fault tree events to their precursors, and ultimately to basic events for which probability data are available. A fault tree may have many levels, but consecutive levels must be linked through one of two basic types of gates: .AND. gates and.OR. gates. Symbols for these gates are illustrated in Figure 10.

.AND and .OR. gates may have several inputs, but can only have one output. The output event will occur only if the appropriate combination of input

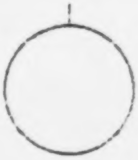
FIGURE 9. FAULT TREE EVENT SYMBOLS

Event representations:

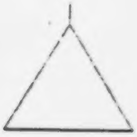
The rectangle identifies an event that results from the combination of events through the input of a logic gate.

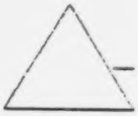


The circle represents a basic event that requires no further development.

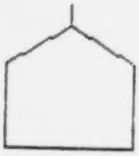


Triangles are used as transfer symbols. A line from the top of the triangle indicates a transfer in, and a line from the side a transfer out.



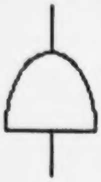
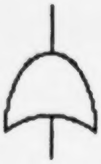


The house is used as a switch to include or eliminate parts of the fault tree that may or may not apply to certain situations.



(Henley and Kumamoto, 1981)

FIGURE 10. FAULT TREE LOGIC GATES

Gate Symbol	Gate Name	Causal Relation
	AND gate	Output event occurs if all input events occur simultaneously.
	OR gate	Output event occurs if any one of the input events occur.

(Henley and Kumamoto, 1981)

events occurs. Thus, the output event from an .AND. gate only occurs when all of the input events occur simultaneously, while the output event from an .OR. gate occurs whenever any of the input events takes place.

3.2 Selection of Fault Tree Events

We derived the basic fault tree events by reorganizing the failure mechanisms identified in Section 2.5. Some of these basic events represent combinations of the failure mechanisms listed in Tables 4-6; others are elaborations of events that those tables include as single entries. For example, the fault trees combine all causes of corrosion into two events (internal corrosion and external corrosion) but they delineate several distinct forms of operator error in addition to the broad categories listed in Table 6. In all cases, we have included as much detail in the model as is warranted by the available data. A listing of the changes that we have made is presented in Table 7.

3.3 Hazardous Waste Tank Fault Trees

The hazardous waste tank fault trees are presented in Figures 11 through 16, using the standard symbols discussed in Section 3.1 of this report. In these figures, we have assigned all of the basic events coded names, such as "MOPMOE" or "B13." Because we used some of the same labels in the computer programs, we were required to restrict their lengths to a limited number of characters. Since these labels are sometimes cryptic, the fault trees also include brief translations. Further explanation of these basic events (including derivations of their probability distributions) are presented in Appendix A; the more important events (such as tank corrosion and pipe corrosion) will be discussed more thoroughly in Chapter 4.

We have designed the fault trees to be as general as possible, so that a single set of trees can be used for all possible tank configurations. This means that the trees contain component systems that are not present in all configurations. Our computer model is designed so that these optional branches can be switched on or off depending on the requirements of the tank system being modeled. For optional branches connected to .AND. gates, this is done by treating the absent component as though it is in a

TABLE 7. REORGANIZATION OF FAILURE MECHANISMS FOR USE IN FAULT TREES

We included the following failures in our baseline probabilities for tank or pipe ruptures or flange leaks.

- Poor material selection
- Poor component selection
- Inadequate structural support
- Poor subgrade preparation
- Improper materials installed
- Miscellaneous external catastrophes (vehicle collision, airplane crash, etc.)

We included variations in the following factors in our baseline corrosion model:

- Internal temperature
- External temperature
- Humidity
- Air quality

We included the following factors in our baseline estimates of ancillary equipment failure rates:

- Power failure
- Equipment aging
- Poor component selection
- Damage during installation
- Improper component installed
- Poor maintenance

We pruned the following factor as extremely low-probability:

- Pump Rupture

We have made the following elaborations on the failure mechanisms listed in Tables 4-6.

- We have divided operator errors into errors of commission and errors of omission.
- We have divided process control equipment into several categories, including automatic shut-down systems, level controllers, and high level alarms.

FIGURE 11. HAZARDOUS WASTE TANKS: BASIC FAULT TREE

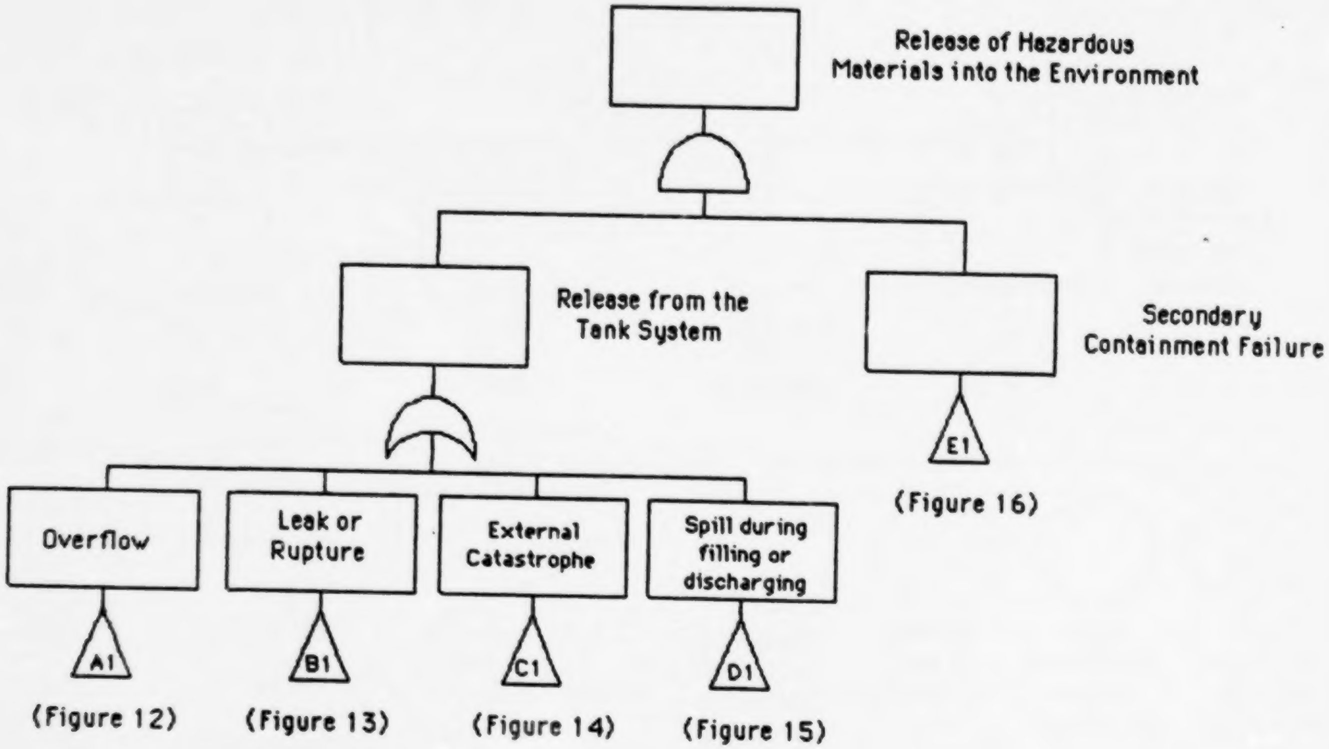

Release of Hazardous Materials into the Environment
Release from the Tank System
Secondary Containment Failure
E1
(Figure 16)
Overflow
Leak or Rupture
External Catastrophe
Spill during filling or discharging
A1
B1
C1
D1
(Figure 12)
(Figure 13)
(Figure 14)
(Figure 15)

FIGURE 12A. OVERFLOWS

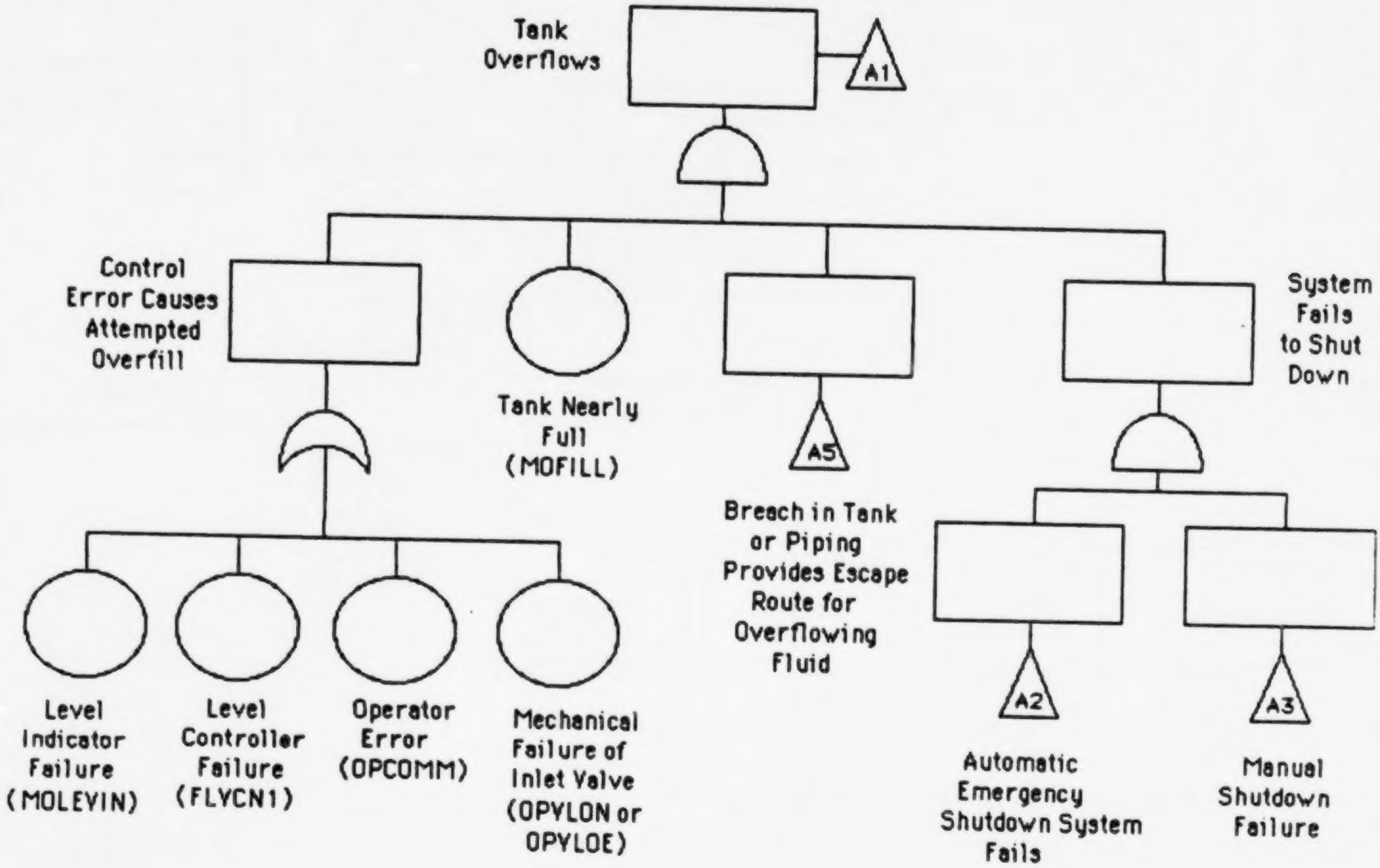

Tank Overflows
A1
Control Error Causes Attempted Overfill
Tank Nearly Full (MOFILL)
A5
Breach in Tank or Piping Provides Escape Route for Overflowing Fluid
System Fails to Shut Down
Level Indicator Failure (MOLEVIN)
Level Controller Failure (FLYCN1)
Operator Error (OPCOMM)
Mechanical Failure of Inlet Valve (OPYLON or OPYLOE)
A2
Automatic Emergency Shutdown System Fails
A3
Manual Shutdown Failure

FIGURE 12B. OVERFLOWS (cont.)

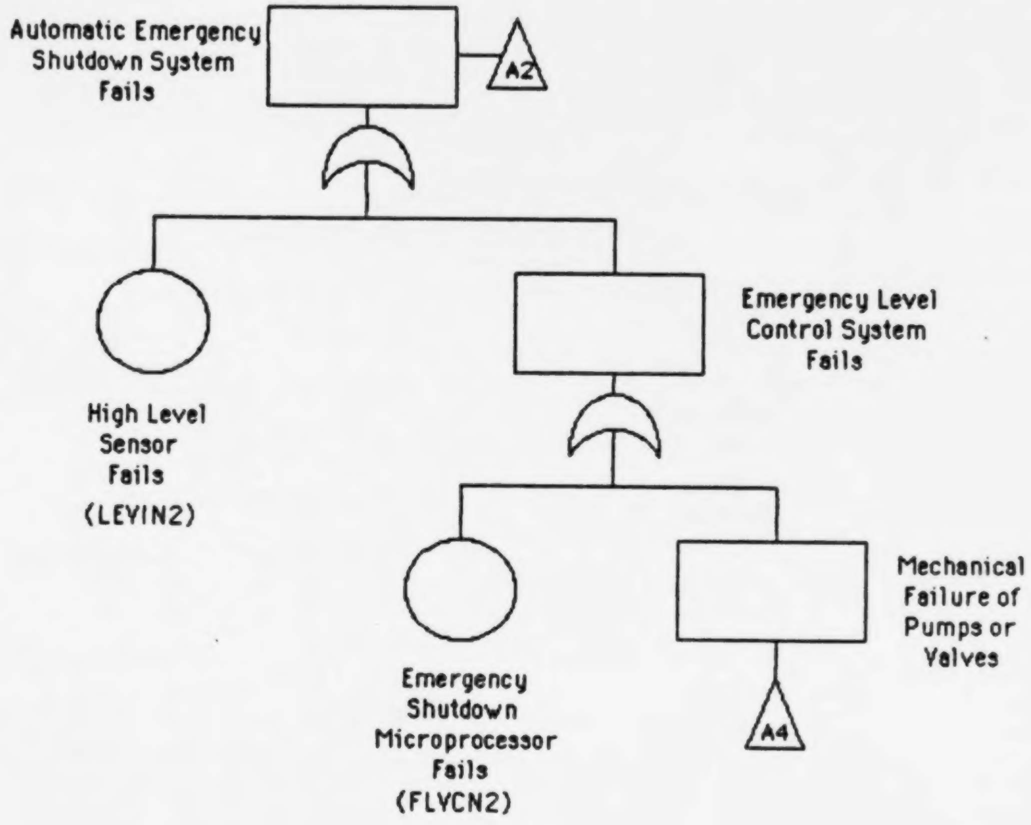

Automatic Emergency Shutdown System Fails
A2
High Level Sensor Fails
(LEVIN2)
Emergency Level Control System Fails
Emergency Shutdown Microprocessor Fails
(FLVCN2)
Mechanical Failure of Pumps or Valves
A4

FIGURE 12C. OVERFLOWS (cont.)

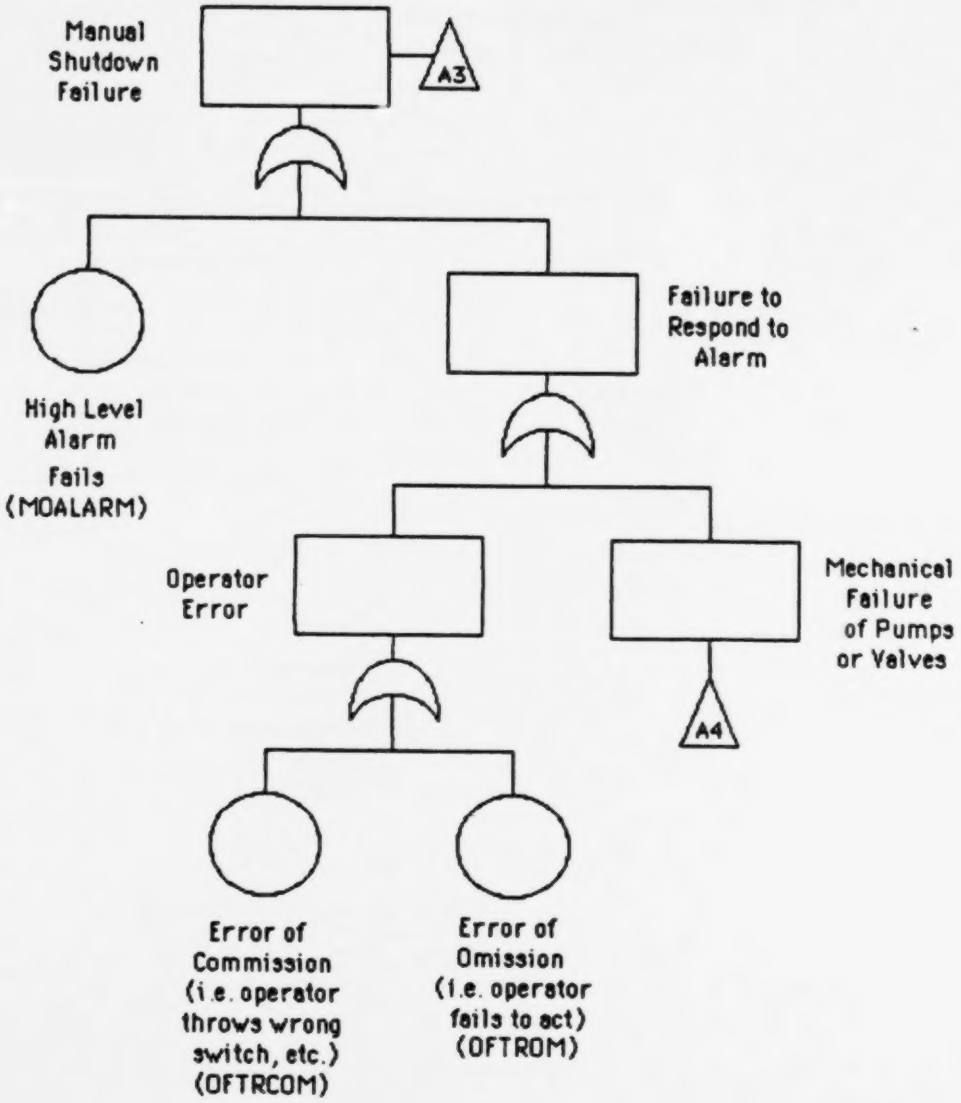

Manual Shutdown Failure
A3
High Level Alarm Fails (MOALARM)
Failure to Respond to Alarm
Operator Error
Mechanical Failure of Pumps or Valves
A4
Error of Commission (i.e. operator throws wrong switch, etc.) (OFTRCOM)
Error of Omission (i.e. operator fails to act) (OFTROM)

FIGURE 12D. OVERFLOWS (cont.)

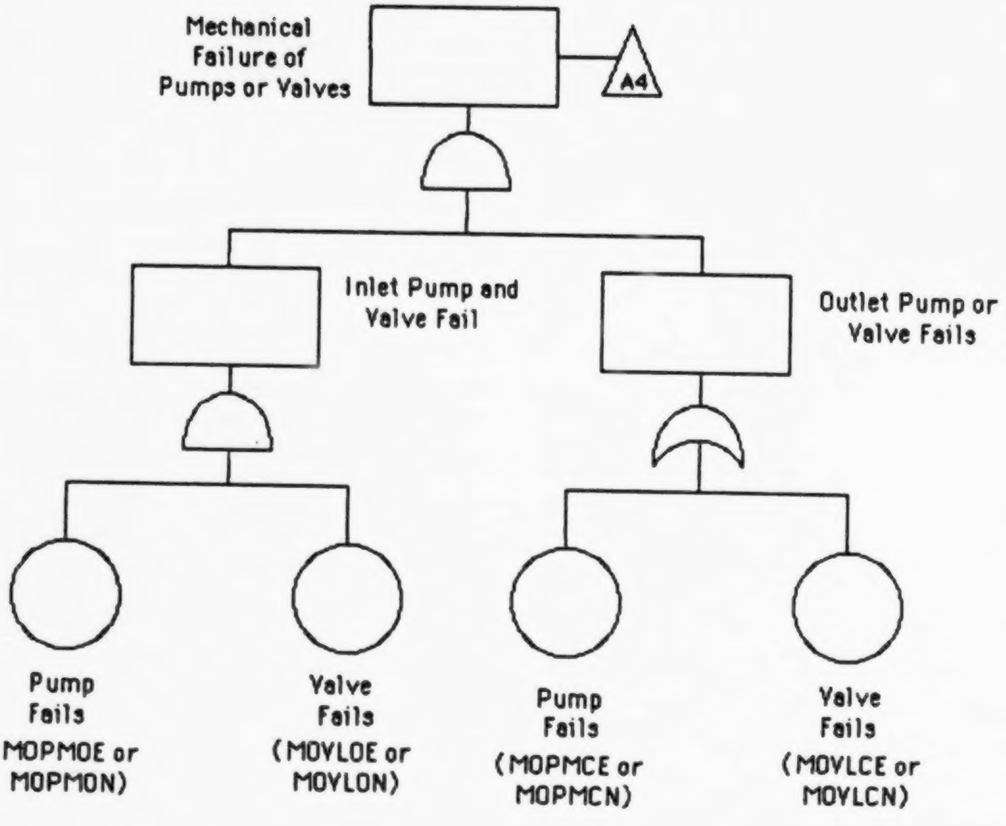

Mechanical Failure of Pumps or Valves
A4
Inlet Pump and Valve Fail
Outlet Pump or Valve Fails
Pump Fails (MOPMOE or MOPMON)
Valve Fails (MOVLOE or MOVLON)
Pump Fails (MOPMCE or MOPMCN)
Valve Fails (MOVLCE or MOVLCN)

FIGURE 12E. OVERFLOWS (cont.)

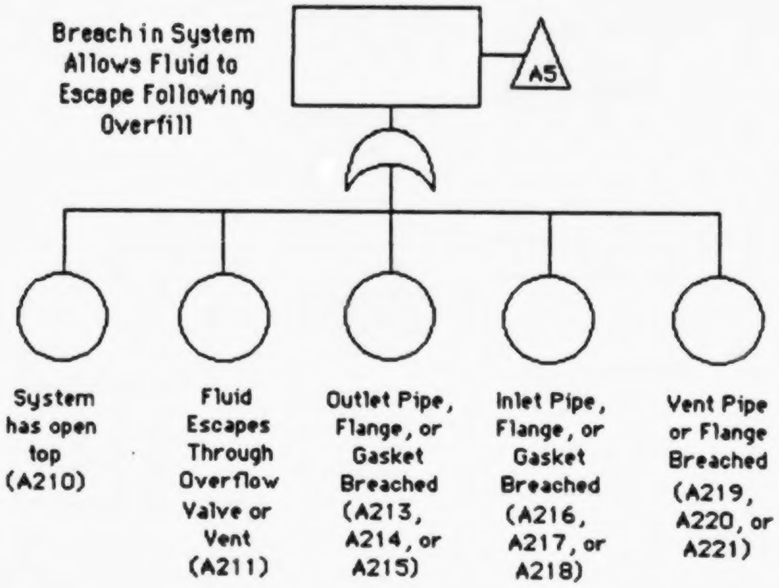

Breach in System Allows Fluid to Escape Following Overfill
A5
System has open top (A210)
Fluid Escapes Through Overflow Valve or Vent (A211)
Outlet Pipe, Flange, or Gasket Breached (A213, A214, or A215)
Inlet Pipe, Flange, or Gasket Breached (A216, A217, or A218)
Vent Pipe or Flange Breached (A219, A220, or A221)

FIGURE 13A. LEAKS AND RUPTURES

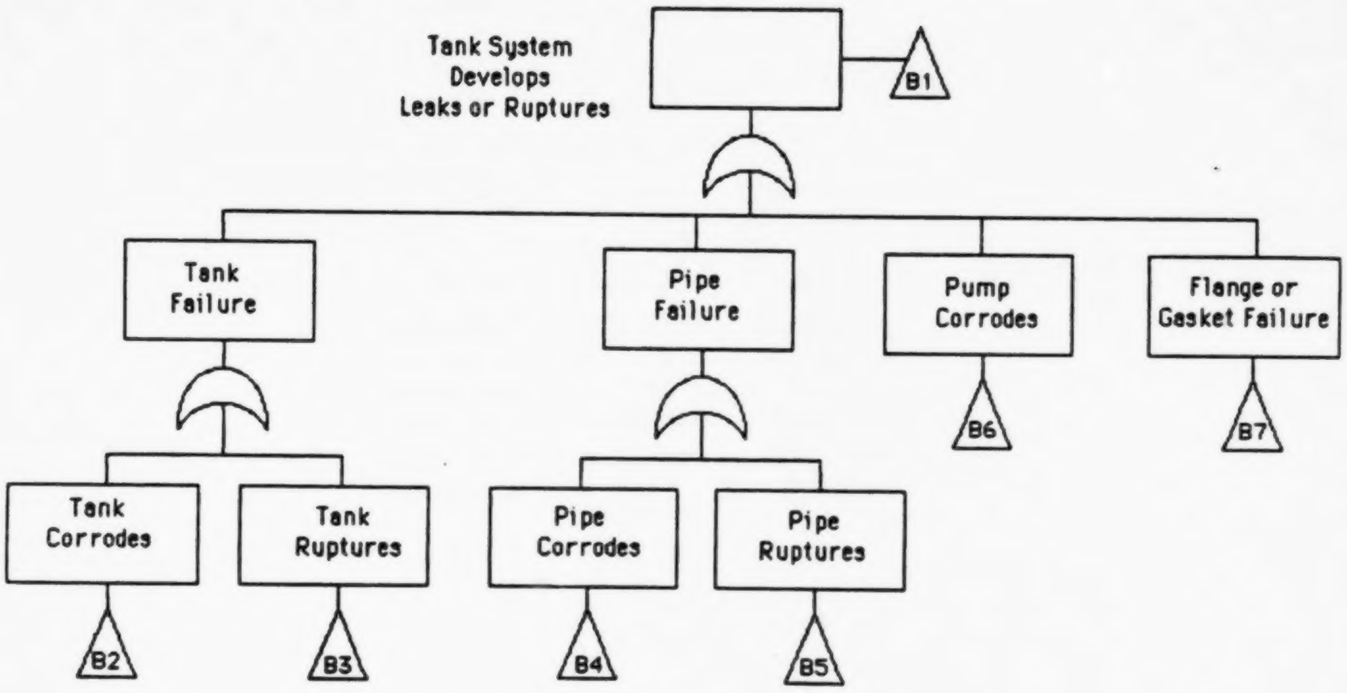
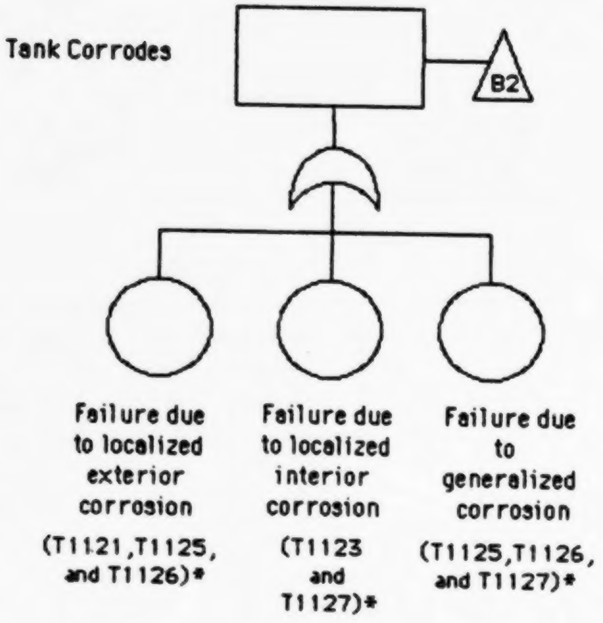

Tank System
Develops
Leaks or Ruptures
B1
Tank
Failure
Pipe
Failure
Pump
Corrodes
Flange or
Gasket Failure
B6
B7
Tank
Corrodes
Tank
Ruptures
Pipe
Corrodes
Pipe
Ruptures
B2
B3
B4
B5

FIGURE 13B. LEAKS AND RUPTURES (cont.)


Tank Corrodes
B2
Failure due to localized exterior corrosion (T1121, T1125, and T1126)*
Failure due to localized interior corrosion (T1123 and T1127)*
Failure due to generalized corrosion (T1125, T1126, and T1127)*

*These event labels describe different aspects of the tank corrosion model. They are explained in Appendix A.

FIGURE 13C. LEAKS AND RUPTURES (cont.)

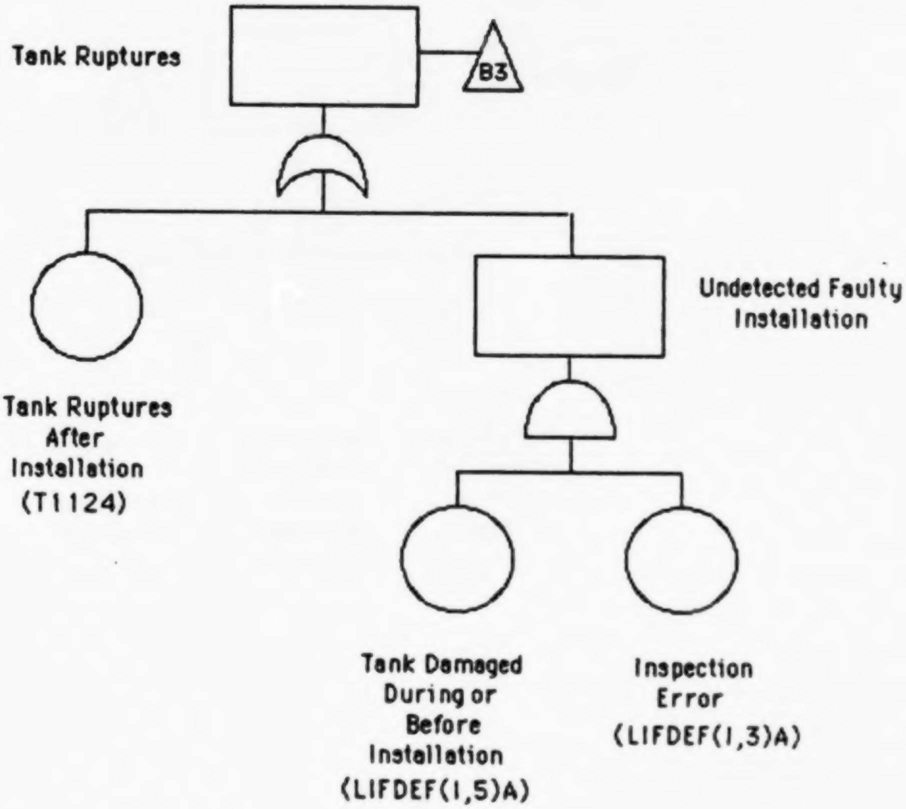
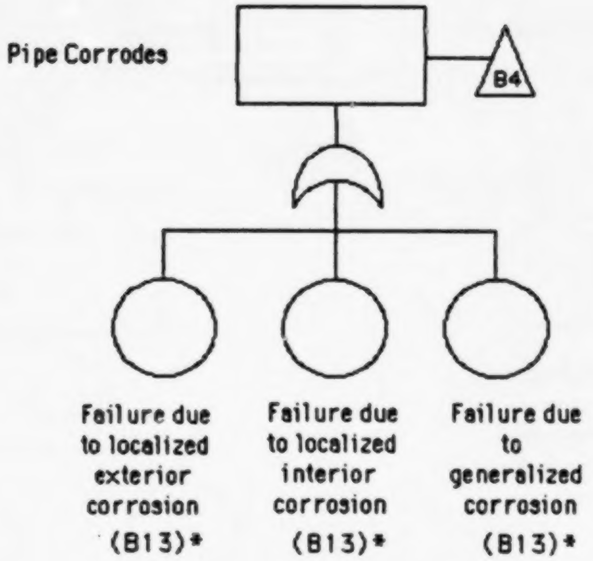

Tank Ruptures
B3
Undetected Faulty Installation
Tank Ruptures After Installation (T1124)
Tank Damaged During or Before Installation (LIFDEF(1,5)A)
Inspection Error (LIFDEF(1,3)A)

FIGURE 13D. LEAKS AND RUPTURES (cont.)


Pipe Corrodes
B4
Failure due to localized exterior corrosion (B13)*
Failure due to localized interior corrosion (B13)*
Failure due to generalized corrosion (B13)*

* All forms of pipe corrosion are included in Appendix A under this one label.

FIGURE 13E. LEAKS AND RUPTURES (cont.)

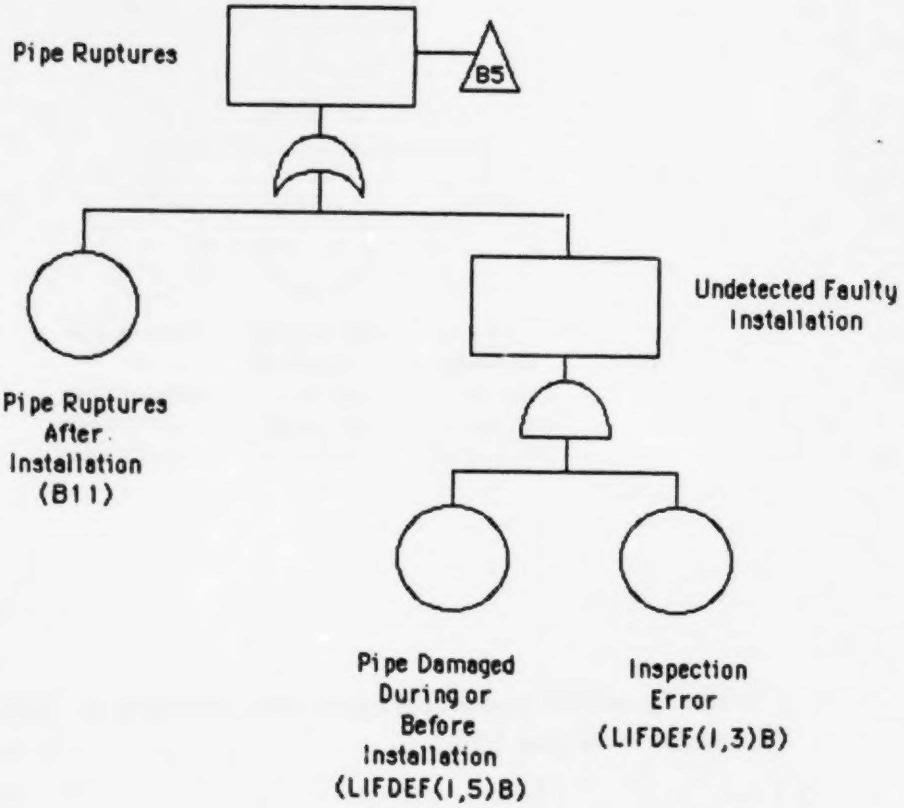
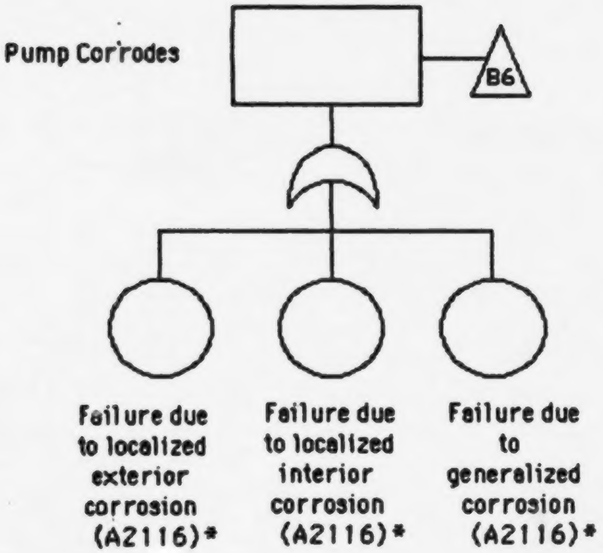

Pipe Ruptures
B5
Undetected Faulty Installation
Pipe Ruptures After Installation (B11)
Pipe Damaged During or Before Installation (LIFDEF(1,5)B)
Inspection Error (LIFDEF(1,3)B)

FIGURE 13F. LEAKS AND RUPTURES (cont.)


Pump Corrodes
B6
Failure due to localized exterior corrosion (A2116)*
Failure due to localized interior corrosion (A2116)*
Failure due to generalized corrosion (A2116)*

* All forms of pump corrosion are included in Appendix A under this one label.

FIGURE 13G. LEAKS AND RUPTURES (cont.)

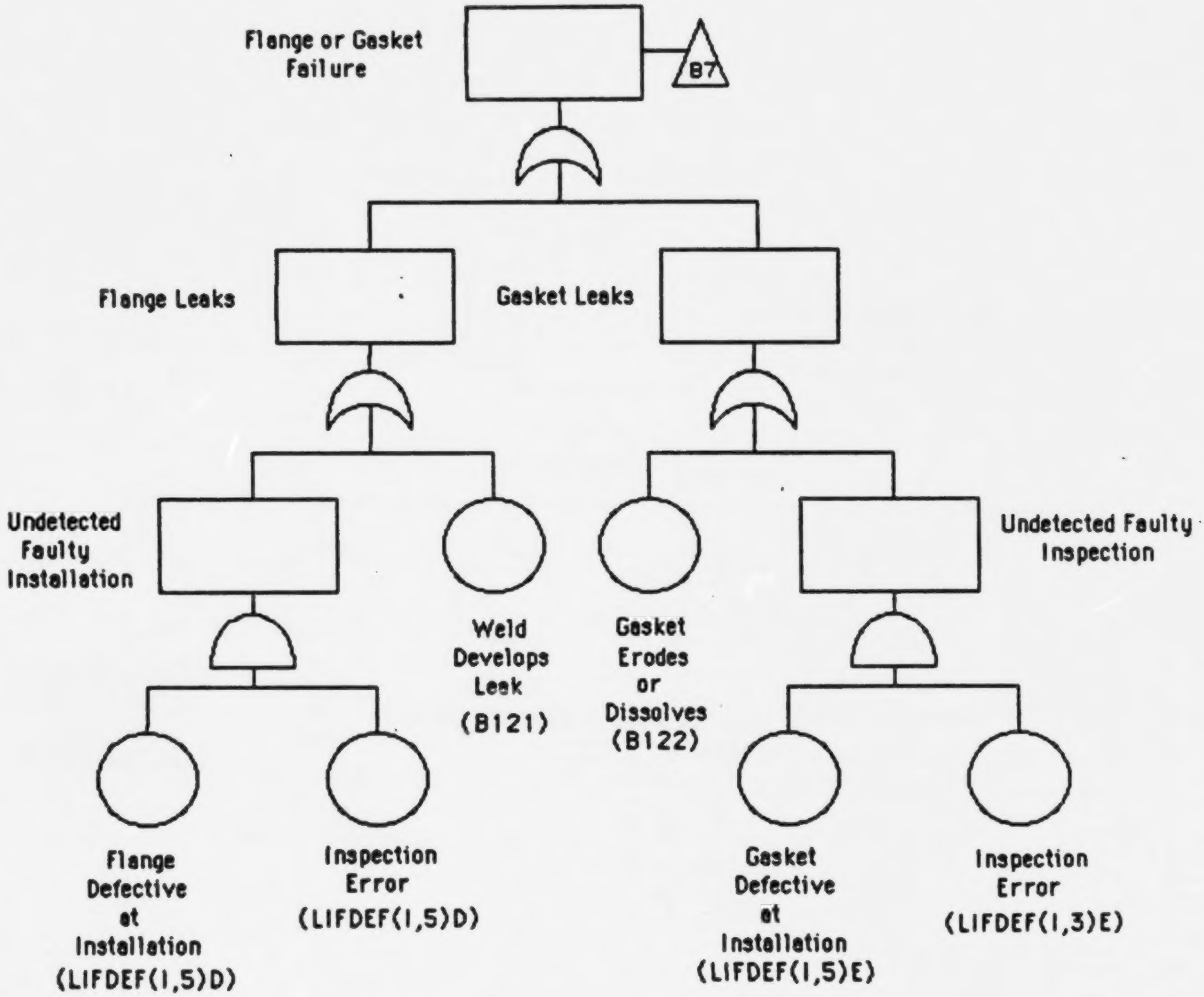

Flange or Gasket Failure
B7
Flange Leaks
Gasket Leaks
Undetected Faulty Installation
Weld Develops Leak (B121)
Gasket Erodes or Dissolves (B122)
Undetected Faulty Inspection
Flange Defective at Installation (LIFDEF(1,5)D)
Inspection Error (LIFDEF(1,5)D)
Gasket Defective at Installation (LIFDEF(1,5)E)
Inspection Error (LIFDEF(1,3)E)

FIGURE 14. LOSS OF SYSTEM CONTENTS DUE TO EXTERNAL CATASTROPHE

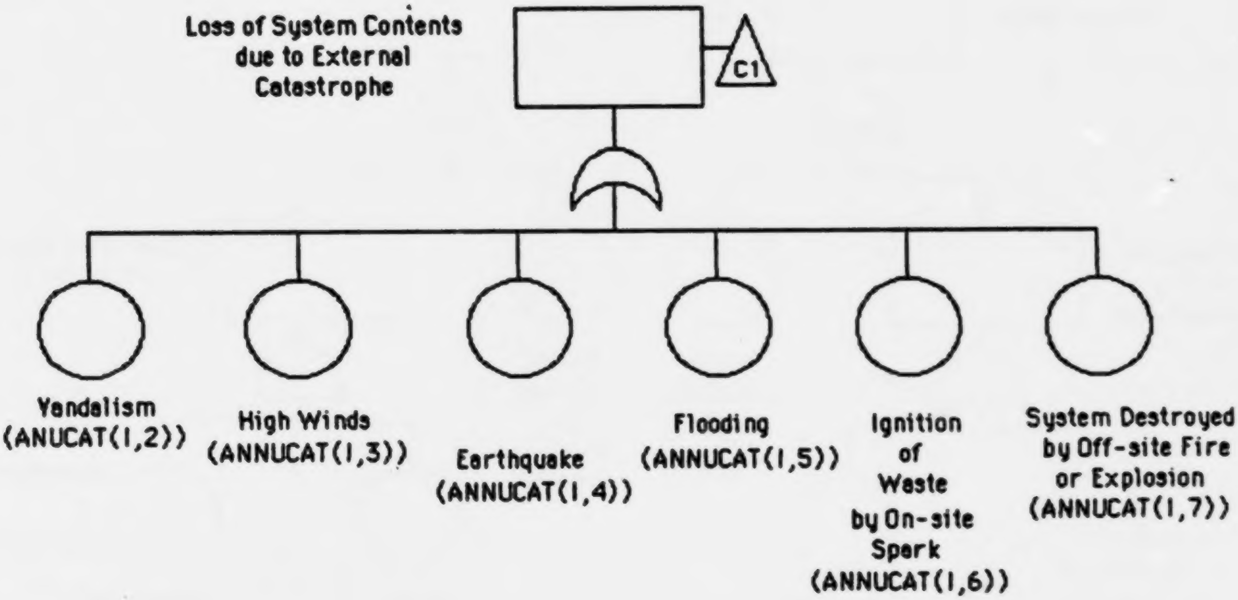

Loss of System Contents due to External Catastrophe
C1
Vandalism (ANUCAT(1,2))
High Winds (ANNUCAT(1,3))
Earthquake (ANNUCAT(1,4))
Flooding (ANNUCAT(1,5))
Ignition of Waste by On-site Spark (ANNUCAT(1,6))
System Destroyed by Off-site Fire or Explosion (ANNUCAT(1,7))

FIGURE 15. SPILL DURING FILLING OR DISCHARGING

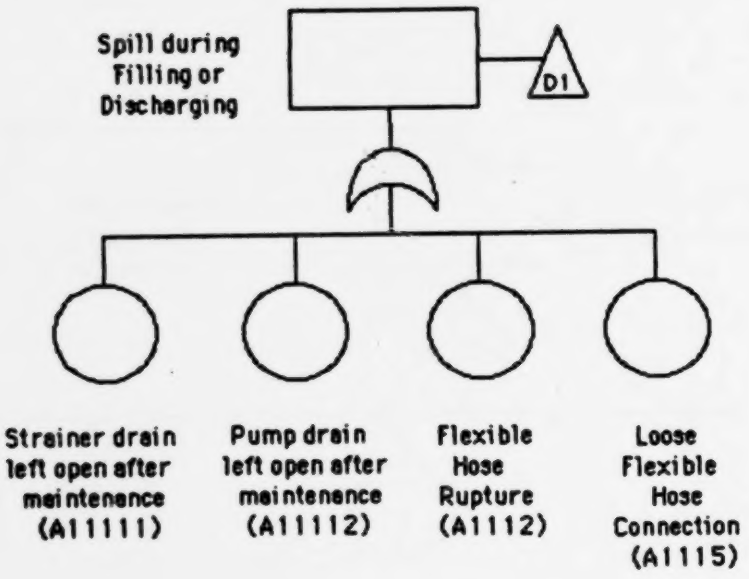
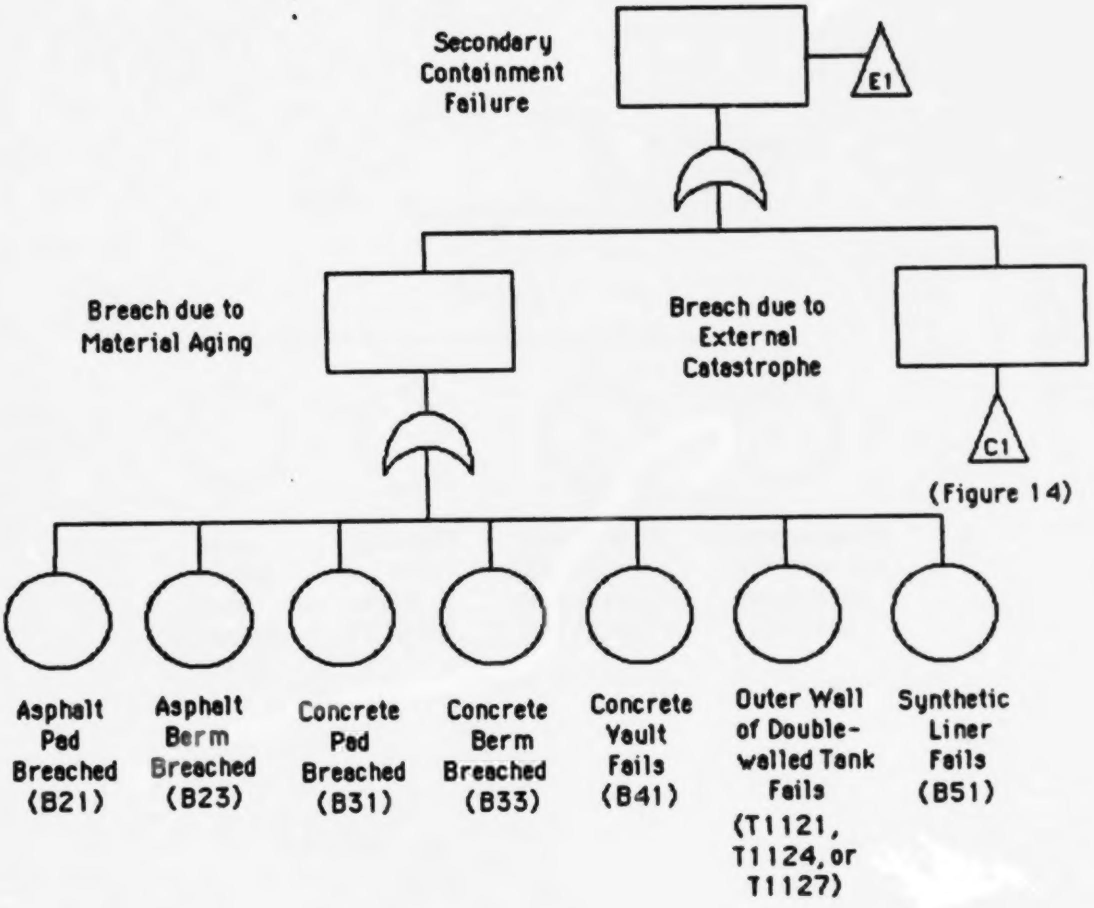

Spill during Filling or Discharging
D1
Strainer drain left open after maintenance (A11111)
Pump drain left open after maintenance (A11112)
Flexible Hose Rupture (A1112)
Loose Flexible Hose Connection (A1115)

FIGURE 16. SECONDARY CONTAINMENT FAILURE


Secondary Containment Failure
E1
Breach due to Material Aging
Breach due to External Catastrophe
C1
(Figure 14)
Asphalt Pad Breached (B21)
Asphalt Berm Breached (B23)
Concrete Pad Breached (B31)
Concrete Berm Breached (B33)
Concrete Vault Fails (B41)
Outer Wall of Double-walled Tank Fails (T1121, T1124, or T1127)
Synthetic Liner Fails (B51)

failed state. Since the .AND. gate will not allow failure unless all of its branches occur simultaneously, there is no difference between eliminating an absent event or treating it as though it has occurred; in either case the .AND. gate will register failure if and only if all of the remaining events occur simultaneously. On the other hand, absent fault tree branches connected to .OR. gates must be treated as though they have not occurred, for otherwise their absence would inevitably cause the .OR. gate to register failure, a result which would not occur unless the component system under consideration were not truly optional.

A couple of simple examples may help to clarify this process. In order to prevent overflows, tank systems generally have emergency shut-down systems. These may be manual or automatic, or both systems might be present at once. Obviously, there will be no emergency shut-down failures unless all existing shut-down systems fail. Thus, the fault tree connects the manual and automatic systems by an .AND. gate. If the automatic system is absent, however, failure will occur whenever the manual system fails. Treating the absent automatic system as though it has already failed will ensure this result. Similarly, if the facility were to rely solely on an automated system, emergency shut-down failure would occur whenever the automatic system failed. This would be the case if the missing manual back-up system were treated as though it were always in a failed state.

As an example of the opposite case, consider the possibility of natural catastrophe. Such catastrophes could result from floods, earthquakes, hurricanes, or tornadoes, so these events are all connected by an .OR. gate. All of these catastrophes, however, are not possible in every geographic location. Thus, if the tank system is not located in a flood-prone region, the flooding event should be deemed not to have occurred, and a natural catastrophe will only result if one of the other events takes place. A similar analysis applies to other failure events connected by .OR. gates.

With this background, it is now possible to turn to a more detailed analysis of the individual fault trees.

The basic tank failure fault tree is presented in Figure 11. This fault tree contains the overall top event (release of hazardous wastes to the environment) and identifies the general mechanism by which it might occur. As is indicated by this figure, uncontained releases may only occur if two intermediate events occur simultaneously: a failure of the tank system itself, and the failure (or absence) of secondary containment. Tank releases are described in Figures 12 through 15; secondary containment failures are described in Figure 16.

Tank System Failures

Tank system failures may be grouped into four categories: overflows, leaks and ruptures, external catastrophies, and spills during filling or discharge operations.

Overflows. The overflow fault trees are presented in Figures 12A through 12E. As the tank overflow fault tree (Figure 12A) shows, four events must occur before an overflow can result: the tank must be close enough to full that an overflow is possible; there must be a control error resulting in an attempt to add too much fluid to the tank; there must be a failure of the emergency shut-down system; and there must be a route by which overflowing fluid may escape from the tank.

All four of these events must occur before any tank system can overflow, but the manner in which they may arise varies with the sophistication of the tank's control system, the sophistication of its emergency shut-off system, and the manner in which it is filled and discharged. We have therefore modeled two types of control systems (automatic and manual), three types of emergency shut-off systems (automatic, manual, and automatic with manual back-up), and two general types of fill/discharge processes (discrete batches and continuous throughput). The fault trees, which apply equally well to storage or treatment tanks, allow us to model any combination of these designs, but in practice only certain designs are likely. Table 8 presents a complete list of the level control, emergency shut-off, and fill/discharge systems which we consider to be likely. As this table indicates, we have assumed that tanks with automatic level controls also have automatic emergency shut-off controls, and that facilities with automatic emergency shut-off generally maintain manual shut-off controls as back-ups. In addition, we have assumed that continuous treatment tanks use automatic controls, while batch treatment tanks use manual controls. We

TABLE 8. FILL/DISCHARGE, LEVEL CONTROL, AND EMERGENCY SHUT-OFF SYSTEMS

Type of Tank	Fill/Discharge Process	Level Control System	Emergency Shut-Off System
STORAGE			
	Batch	Manual	Manual
	Continuous	Manual	Manual
	Continuous	Automatic	Automatic (manual back up)
TREATMENT			
	Batch	Manual	Manual
	Automatic	Automatic	Automatic (manual back-up)

have generally assumed that storage tanks are batch systems with manual controls, but we have also modeled continuous storage tanks. We have assumed that such facilities are used as settling tanks and only rely on manual controls if they maintain such a large freeboard that careful level monitoring is unnecessary.

The first requirement for any of these tank systems to overflow is that the tank be close enough to being full that an overflow is even possible; a half-empty 10,000 gallon tank, for example, cannot be overflowed by the addition of a 1,000-gallon batch. How often a potential overflow situation arises is therefore a function of the system design and operating policy. Our assumptions for the various types of tanks are listed in Table 9. In general, we have assumed that potential overflow situations occur constantly for continuous treatment processes (because fluid is regularly added when the tank is already filled to its normal operating depth), once per batch for batch treatment processes (because the operator is adding fluid from a storage tank which we assume to have larger capacity than the treatment tank itself), and infrequently (once per year) for storage tanks (because storage tanks are generally filled in comparatively small batches and pumped-out before they get dangerously full; we make the conservative assumption that once per year there is a fluctuation in waste-generation rates or a failure to follow the pump-out schedule, thereby allowing the tank to become full). Continuous storage tanks (settling tanks) are modeled on a case-by-case basis by comparing their daily throughputs to their normal reserve capacities.

Even if the tank is full, there must also be a control error before an overflow can result. Such an error would occur if a malfunction in a level indicator causes too much fluid to be added to the tank (either in automatic or manual systems), if an automatic level controller fails, if the operator of a continuous system makes an error in the morning start-up routine, if the operator of a manual system ignores the liquid level indicator and adds too much fluid, or if an automatic inlet valve sticks in the open position.

These control errors, however, will not result in an overfill unless the emergency shut-down system fails. The most sophisticated emergency shut-

TABLE 9. FREQUENCY OF FILLING A NEARLY-FULL TANK FOR VARIOUS TANK SYSTEMS

Type of Tank System	Frequency of Filling a Nearly Full Tank
TREATMENT TANKS	
Continuous	100% of operating day
Batch	Once per batch
STORAGE TANKS AND ACCUMULATION TANKS	Once per year

down systems (depicted in Figure 12B and 12D), consist of a high level sensor connected to a microprocessor which automatically shuts down the inlet pump and valve. If the inlet system fails to shut down, the microprocessor instead adjusts the outlet pump and valve to increase the rate of out-flow.

All of these components are subject to failure. Mechanical failure of the pumps and valves, however, will only be critical if both the inlet and outlet pump systems fail; proper operation of either of these systems will prevent the accumulation of excess fluid in the tank. In addition, emergency shut-off will still occur unless both the inlet pump and the inlet valve fail to shut down. If either of these components functions properly, it will cut off the flow of fluid, thereby preventing the overflow. For the outlet pump system, however, the pump is more important than the valve; in continuous processes the valve is always at least partially open, so we have assumed that a change in pumping rate will be effective even if the valve sticks.

Automatic emergency shut-off controls are most likely to be found on continuous treatment tanks (see Table 8), but in order to make the fault trees as general as possible, we have also modeled automatic shut-off systems for batch processes. The only difference between automatic shut-off systems for batch and continuous tanks lies in the outlet pump system. In batch systems, the outlet valve will always be closed while the tank is being filled, so it must be opened before the outlet system can be used to pump out excess fluid. The outlet system will therefore fail if either the pump fails to start or the valve fails to open.

Storage and accumulation tanks are also unlikely to have automatic emergency shut-off systems, but for completeness, we have also included such systems in the model. Since these systems are generally emptied by a pump-out truck, there is no on-site outlet pump, and the emergency shut-off system would only be connected to the inlet pump and valve. A failure of either of these components would therefore result in an emergency shut-off failure.

Emergency shut-off systems for manual treatment and storage tanks are depicted in Figure 12C. In these systems, an overfill will trigger a high-level alarm, thereby summoning the operator, who will then manually shut off the appropriate pumps and valves. Such a manual shut-off system is vulnerable to three types of failure: mechanical failure of the high-level alarm, operator error, or mechanical failure of the pumps or valves. Operator error may result from either a failure to act, or from such improper actions as turning off the wrong pump or opening or closing the wrong valve. Pump and valve failures will have the same effects as they do in the corresponding automatic systems.

The final requirement for an overflow to occur is that there be a route by which the excess fluid may escape (see Figure 12E). For some tank designs, such routes always exist. Open-topped tanks, for example, need no other overflow route, and pump-fed tanks can overflow through their vents. Closed, gravity-fed tanks, however, are less subject to overflow, for the model assumes that their vent pipes open at a level above the highest possible fluid level in their fill tanks. For such tanks, an overfill can only result in leakage if there are corrosion holes or ruptures (cracks) in the fill pipe, the vent pipe, or the outlet pipe or valve, or if there are faulty flanges or gaskets.

Leaks and Ruptures. Leaks and ruptures are the second major category of system failures. Their fault trees are presented in Figures 13A through 13G. Leaks are losses due to corrosion; ruptures include both large cracks and small weld failures. As is shown by Figure 13A, such failures may develop in the tank, pipes, pumps, flanges, or gaskets. For all of these components, the basic failure routes are the same: they may crack because of component defects or due to strains caused by settling, vibration, temperature changes, faulty installation, or vehicle crashes; or they may corrode due to the combination of internal and external attack.

Some of these failure routes have been pruned from Figure 13. Pump ruptures, for example, have been omitted because they are extremely unlikely ($p < 10^{-7}$), and flange corrosion has been combined with the corrosion of the tank and pipes. Similarly, although they are subject to both rupture and corrosion, valves are not separately listed in Figure 13, but are instead included as parts of the attached pipe segments.

Corrosion is modeled in Figures 13B (for tanks), 13D (for pipes), and 13F (for pumps). For each of these components, these figures identify three basic types of failure: localized external pitting, localized internal pitting, and the generalized corrosion of large segments of the component wall. In many cases, several of these mechanisms may occur simultaneously, producing more rapid failure than would result from any mechanism acting alone. In such situations, we combine the corrosion rates, computing the remaining wall-thicknesses for the deepest exterior pits, the deepest interior pits, and the rest of the component's surface. When one of these wall-thicknesses reaches zero, we assume that a leak develops. Continued corrosion will enlarge the holes, increasing the leak rates until the loss is detected and the component is replaced. See Chapter 4 of this report for a more detailed discussion of the corrosion model, the hole growth model, and the calculation of leak rates.

Ruptures are modeled in Figure 13C and 13E for tanks and pipes, respectively. These fault trees are very similar. For either type of component, ruptures may result from one of two sources: undetected installation damage or normal operating hazards. Normal operating hazards may produce ruptures at any time during the facility's life; installation defects will result in immediate failures. We assume that the probability of detecting installation defects depends on the quality of the inspection. The model allows for four types of inspection. The most effective of these is the combination of visual inspection, weld testing, and tightness testing. We assume that this will catch 95% of installation errors. Visual inspection alone we assume to be 50% reliable, and visual inspection with weld testing we assume to be 75% effective. The fourth option is no inspection at all, in which case no defects will be detected. Since inspection requirements are one of the regulatory options being modeled, the choice of inspection levels is made by parameter selection at the beginning of each simulation.

The final category of leaks and ruptures are flange and gasket failures. These are depicted together in Figure 13G. Flange leaks are similar to tank or pipe ruptures, resulting from improper installation or normal operating hazards. Gaskets, however, have different failure mechanisms. They may leak due to improper installation, but if they are properly installed, they are subject to gradual attack by the fluid, rather than to sudden cracking. This gradual attack is a corrosion-like process (although the mechanism is quite different), and we have modeled it by computing an annual gasket-disintegration rate. This process will be discussed in greater detail in Chapter 4, below.

External Catastrophies. External catastrophies are depicted in Figure 14. They are all assumed to cause the sudden loss of the system's entire contents, and may result from vandalism, high winds (tornadoes or hurricanes), earthquakes, floods, on-site fires, or damage from nearby fires or explosions. Not all of these events will occur for any given system design; non-flammable wastes cannot burn, and not all geographic regions are vulnerable to all of the other hazards. Thus, these events are controlled by the choice of waste streams and a set of geographic variables. External catastrophies could have been included with leaks and ruptures, but because they are exogenous events uninfluenced by system design (except that below-ground tanks are safe from wind-storms and relatively safe from nearby fires or explosions), we have modeled them separately.

The final type of tank failures are spills other than overflows during filling and discharging. These releases, depicted in Figure 15, result when the operator fails to close a pump or strainer drain after maintenance, or when a portable flexible hose ruptures or is improperly connected. Which of these spill mechanisms is possible depends on the details of the system design. Treatment systems, for example, do not use portable hoses for fluid transfer, nor do they use strainers. Their fill and discharge pumps, however, are maintained annually, and there is a chance that the operator will forget to close a pump drain afterward. This will produce a spill the next time the pump is used. Storage and accumulation tanks, on the other hand, are pumped out by flexible hose. Spills are possible if this hose ruptures or is improperly attached. In addition, the pump-out truck carries a portable pump and strainer, which can produce a spill if the tank being pumped out is the first one to be visited after faulty pump or stainer maintenance. We have not modeled fill pumps and strainers for such tanks, however, for these pieces of equipment, if they even exist, are generally located at the upstream end of the tank's fill pipe, and are more closely associated with the operator's process equipment than they are with the storage or accumulation tank.

Secondary Containment

Secondary-containment systems generally consist of berms, pads, or underground vaults designed to retain fluid following a breach in the tank system itself. In addition, some tanks have two closely-spaced walls, with a liquid sensor in the middle. Thus, a breach in either wall will trigger the liquid sensor, (either due to leaking waste or to infiltrating soil moisture), allowing the owner to repair the tank before a release can occur. A variety of secondary-containment systems are possible, but in general, above-ground tanks employ berms and concrete or asphalt pads, while underground systems use concrete vaults (with or without a liner) or double-walled tanks.

Secondary-containment systems may be complete or partial. Complete systems encompass the entire tank system and all of its ancillary equipment. Partial systems only contain releases from certain components. In-ground or on-grade tank systems, for example, often have only partial secondary-containment systems. These systems will contain above-ground releases, but will not contain releases from the on- or below-grade portions of the tank. We account for partial secondary-containment systems by first determining the location of the particular primary-containment leak. Then, based on the design of the modeled system, we determine which, if any, secondary-containment devices are involved, and then determine whether the appropriate component has failed. This process also allows us to specify separate secondary-containment systems for different portions of the hazardous waste facility. Thus, tanks may be placed in one secondary-containment system, while pipes are placed in another. A pipe leak will therefore only produce a release if the piping secondary-containment system is breached, while a tank leak will only produce a release if the tank secondary-containment system has failed. If pipes and tanks use separate secondary-containment systems, the secondary-containment fault tree must be evaluated independently for each system.

Secondary-containment failures are depicted in Figure 16. As Figure 16 indicates, there are two basic causes of secondary-containment failure: breaches due to external catastrophe, and breaches due to internal events such as settling, freeze/thaw action or normal material aging. External catastrophes which may breach secondary containment are the same as those which may breach the tank system itself. Because these events usually involve serious structural damage to the entire tank facility, we have assumed that whenever such catastrophes breach one containment system, they also breach the other. Thus, this type of secondary-containment failure always occurs in concert with the failures listed in Figure 14.

Failures due to internal events, on the other hand, are independent processes for the tank system and the secondary-containment system. Thus, these types of failures may occur at different times for each system. A release to the environment will only occur if both systems are in failed states at the same time.

Conclusion

As the preceding discussions reveal, the fault trees present a flexible general framework allowing a number of system design options. In addition, the preceding discussions should also have revealed that evaluation of the fault trees is not a one-time procedure. Instead, the fault trees represent a dynamic system, with various events occurring at different times and with events being switched on and off as failures occur and are detected and repaired. Thus, since the probability of many failure events (most notably corrosion) depends on the age of the component under consideration, the fault trees and leak detection systems must be continuously monitored to determine the timing and duration of any failures that develop. It is for this purpose that we developed the Monte Carlo Simulation Model, the details of which will be discussed in the next chapter.

4.0 MONTE CARLO SIMULATION MODEL

4.1 Introduction

The fault trees developed in Chapter 2 form the basis for the computerized Monte Carlo simulation model. This model simulates each of the fault tree events by drawing a random number to determine if that event occurs. The computer then evaluates the fault tree logic gates to determine whether the events that occur in month one are sufficient to cause a release. If no release occurs, the computer determines whether inspection or scheduled maintenance will cause any components to be replaced, advances the facility age by one month, and draws another series of random numbers to determine if any additional components fail during month 2. To save computer time, however, some fault tree branches are only evaluated once per model year. These branches represent events whose probabilities are low enough that the possibility of multiple occurrences in any given year can be safely ignored. In general, we have assumed that events with annual probabilities of less than 3% need only be evaluated annually (such events have less than one chance in a thousand of occurring twice in any given year), while those with higher probabilities need to be evaluated monthly. When one of the annually-evaluated events occurs, the computer determines the exact month of failure by the simple expedient of drawing a random number between 0 and 12. This process of repeated fault tree evaluation continues until a failure occurs or until the entire time period to be modeled has elapsed.

When a release occurs, the computer interrupts this process to determine the leak rate and whether or not the leak is detected in the month in which it began. If the leak is detected, the computer determines the exact detection period, calculates the total loss volume, and replaces the failed components. If the leak is not detected, the computer carries it into the next month, evaluates the fault trees for new leaks, increments the sizes of existing corrosion holes (but not of ruptures), and determines which leaks can now be detected.

The output from this procedure is a time series of releases, identified by component, starting date, ending date, total volume of loss, and method of detection. This time series we call the "release profile" from the modeled tank. Once the release profile is completed, the simulation is rerun through hundreds of iterations, generating a new release profile for each iteration. If enough iterations are run, these release profiles represent the spectrum of possible behavior for the modeled system, and can be used to generate average, median, and extreme values for releases from various components. These values can be compared for various system designs in order to determine their relative performances.

A simplified flow chart for this entire process is presented in Figure 17. A more complete flow chart, identifying individual computer subroutines, is contained in Appendix E. Appendix E also contains the computer code for the simulation model.

The flow chart in Figure 17 identifies five basic components of the simulation model. In order of occurrence, these are:

- The choice of system design and the calculation of the related system parameters;
- The evaluation of the fault trees to determine the occurrence of stochastic events;
- The calculation of leak rates;
- The determination of detection lags; and
- The presentation of results.

The following sections will discuss the details of the first four of these steps. Section 4.2 will list the user-chosen parameters employed by the model and will explain the impact of these parameters on system behavior. Section 4.3 will give a general explanation of the basic techniques used for modeling the occurrence of stochastic events, while Section 4.4 will list the probabilities used for each of the basic fault tree events. Sections 4.5, 4.6, 4.7, 4.8, and 4.9 will explain in more detail the manner in which we calculate leak rates for tank corrosion, pipe corrosion, pump and valve corrosion, erosion, and gasket deterioration, respectively. Section 4.10 will explain how the model determines hole sizes, and Section 4.11 will explain the calculation of leak rates. Section 4.12 will

FIGURE 17. FLOW CHART FOR SIMULATION MODEL

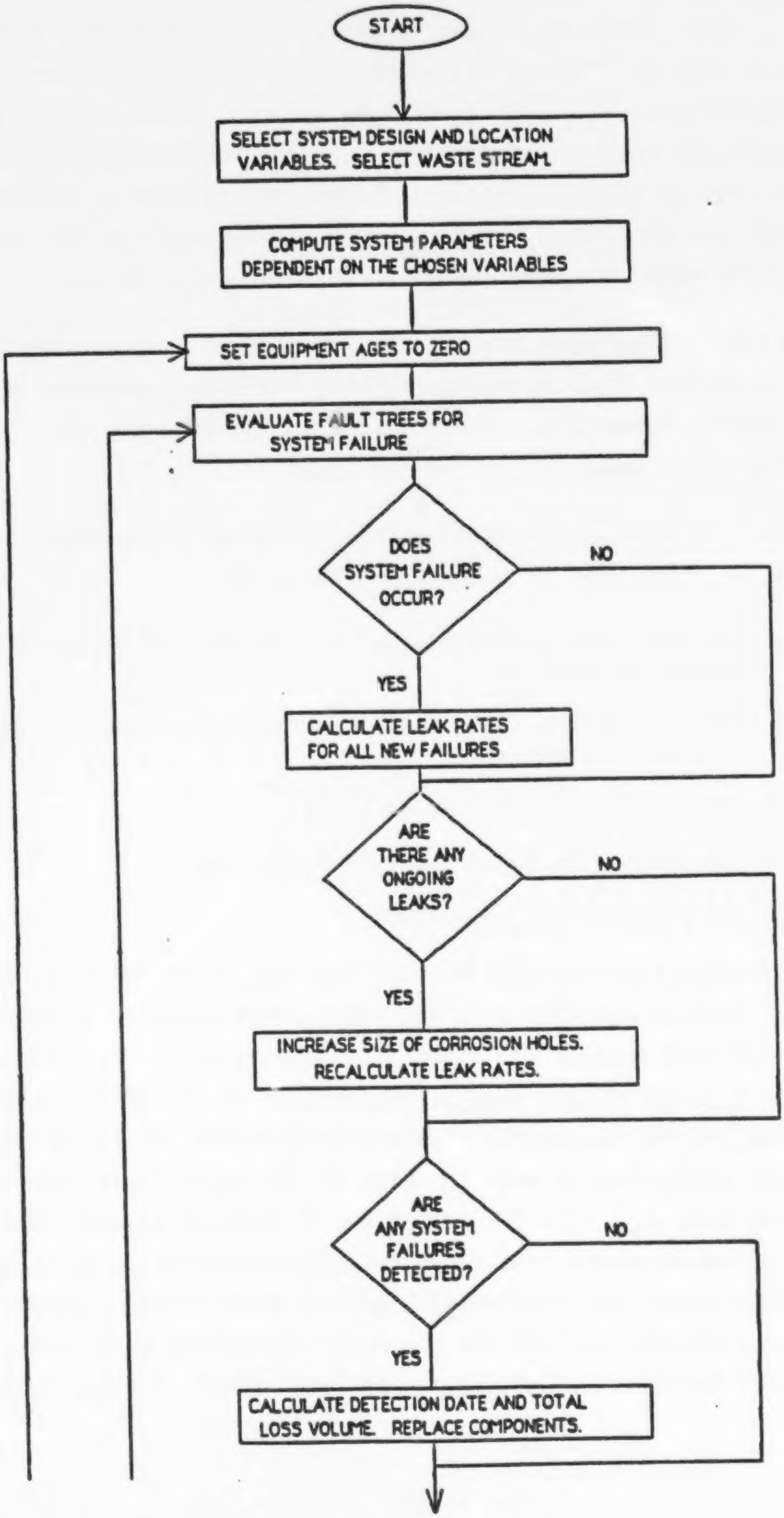
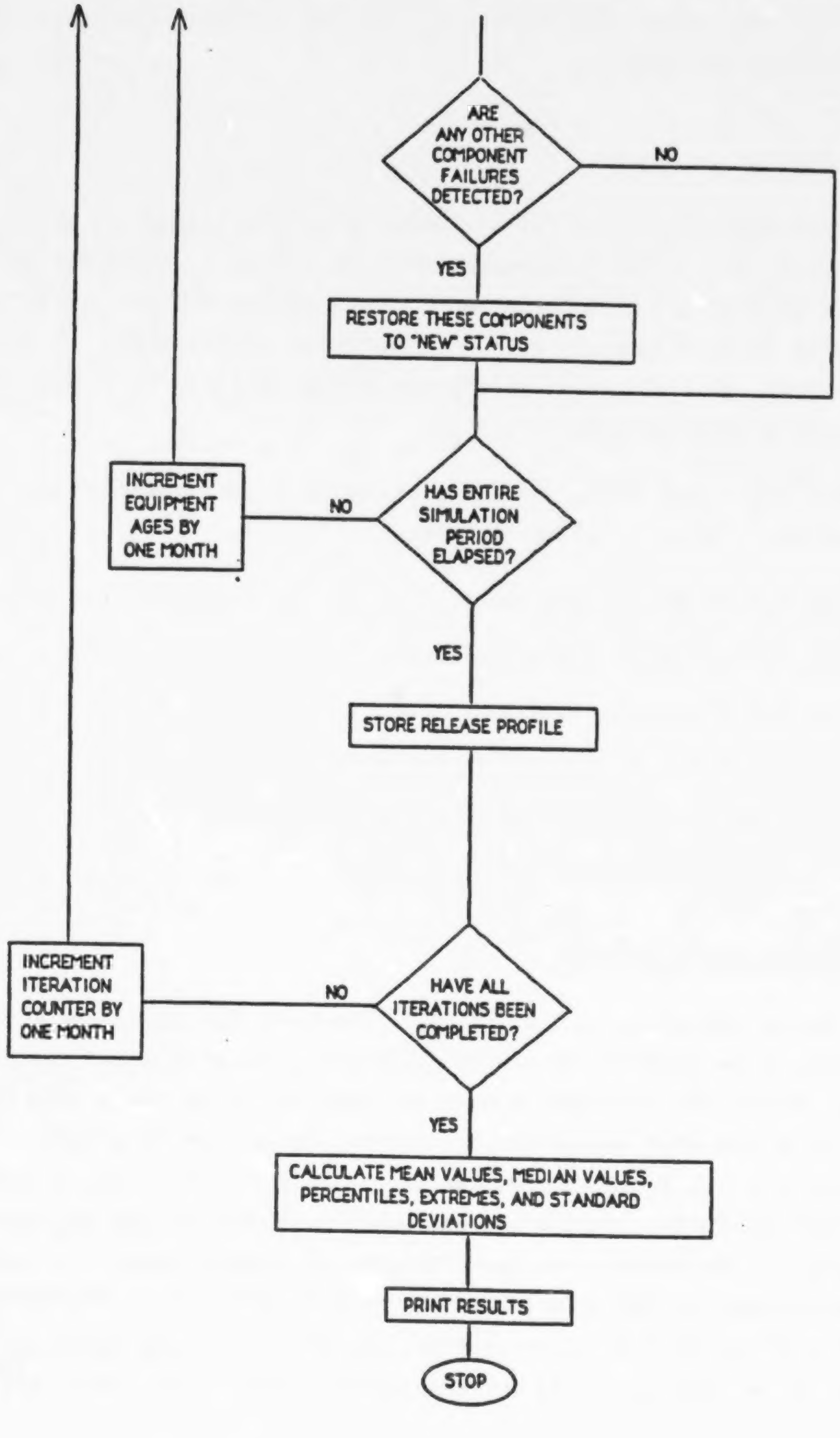

START
SELECT SYSTEM DESIGN AND LOCATION VARIABLES. SELECT WASTE STREAM.
COMPUTE SYSTEM PARAMETERS DEPENDENT ON THE CHOSEN VARIABLES
SET EQUIPMENT AGES TO ZERO
EVALUATE FAULT TREES FOR SYSTEM FAILURE
DOES SYSTEM FAILURE OCCUR?
NO
YES
CALCULATE LEAK RATES FOR ALL NEW FAILURES
ARE THERE ANY ONGOING LEAKS?
NO
YES
INCREASE SIZE OF CORROSION HOLES. RECALCULATE LEAK RATES.
ARE ANY SYSTEM FAILURES DETECTED?
NO
YES
CALCULATE DETECTION DATE AND TOTAL LOSS VOLUME. REPLACE COMPONENTS.

FIGURE 17. FLOW CHART FOR SIMULATION MODEL (Continued)


ARE ANY OTHER COMPONENT FAILURES DETECTED?
NO
YES
RESTORE THESE COMPONENTS TO "NEW" STATUS
INCREMENT EQUIPMENT AGES BY ONE MONTH
NO
HAS ENTIRE SIMULATION PERIOD ELAPSED?
YES
STORE RELEASE PROFILE
INCREMENT ITERATION COUNTER BY ONE MONTH
NO
HAVE ALL ITERATIONS BEEN COMPLETED?
YES
CALCULATE MEAN VALUES, MEDIAN VALUES, PERCENTILES, EXTREMES, AND STANDARD DEVIATIONS
PRINT RESULTS
STOP

conclude the chapter with an analysis of the various leak detection methods examined by this model.

4.2 User Inputs

The Hazardous Waste Tank Failure Model is general enough to allow us to simulate a wide range of tank systems. As a result, the model has a large number of user-selected parameters. These parameters are listed in Table 10. That table also gives a brief description of the effect of these parameters and lists cross references to the sections of this report explaining these effects.

As this table indicates, there are six general categories of user input variables. These variables include:

- System design parameters,
- Environmental characteristics,
- Waste characteristics,
- Secondary containment characteristics,
- Leak detection system parameters, and
- Simulation control variables.

System Design Parameters.

The system design variables are used to select the storage or treatment process to be modeled, determine construction materials and system capacity, select the corrosion protection features to be built into the tank, and determine what components are above-, below-, or in-ground. These parameters also determine whether the process is continuous or batch, whether the control system and emergency shut-off systems are manual or automatic, and whether the tank is open- or closed-topped. A variety of miscellaneous variables are also included in this group, including the choice of welded flanges or gaskets, the choice of pump location, the interval between pump-outs for storage or accumulation tanks, and the

TABLE 10. USER INPUTS FOR HAZARDOUS WASTE TANK FAILURE MODEL

Variable Description	Possible Choices	Effect	Cross References
SYSTEM DESIGN			
Process for which tank is used	Storage or accumulation Chrome reduction Cyanide oxidation Distillation Evaporation Neutralization Precipitation	Determines number of tanks, pH of contents, number and location of pumps.	Section 2.3
Tank construction material	Carbon steel Stainless steel Fiberglass Concrete	Determines corrosion rate and rupture probability.	Section 4.5
Pipe construction material	Carbon steel Stainless steel Fiberglass	Determines corrosion rate and rupture probability.	Section 4.6
Tank capacity	200-50,000 gallons (underground tanks) 200-unlimited (above- or in-ground tanks)	Influences tank surface area, tank wall thickness, maximum loss volume from major ruptures, hydraulic head for smaller leaks.	Section 4.2
Yearly throughput	Any	Determines inventory monitoring detection threshold, maximum yearly loss volume, total fill/discharge time.	Section 4.2
Number of operating days per year	100-365	Influences failure probabilities for pumps, valves, and system control equipment. Influences annual loss volumes from leaking ancillary equipment.	Section 4.4

TABLE 10. USER INPUTS FOR HAZARDOUS WASTE TANK FAILURE MODEL (Continued)

Variable Description	Possible Choices	Effect	Cross References
SYSTEM DESIGN (Continued)			
Number of operating hours per day	1-24	Influences failure probabilities for pumps, valves, and system control equipment. Influences daily loss volumes from leaking ancillary equipment.	Section 4.4
Location of tank	Above-ground (on-grade) Above-ground (on cradles) In-ground Below-ground	Influences corrosion rate, vulnerability to external catastrophes, and leak rate.	Section 4.2
Tank top	Open Closed	Open tanks overflow more easily.	Section 3.3
Fraction of in-ground tank that is underground	0-100%	Influences corrosion rate and leak rate.	Section 4.5
Location of pipes	Above-ground Below-ground	Influences corrosion rate, vulnerability to external catastrophes, and leak rate.	Section 4.6
Treatment efficiency	0-100%	Determines concentration of hazardous constituent in downstream piping.	Section 2.2, Appendix D
Fraction of main constituent	Any	Determines concentration of hazardous constituent at various stages of the treattment or storage process.	Section 2.2, Appendix D
Fraction of suspended solids	Any	Determines erosion rate when fluid is in motion.	Section 4.8

TABLE 10. USER INPUTS FOR HAZARDOUS WASTE TANK FAILURE MODEL (Continued)

Variable Description	Possible Choices	Effect	Cross References
SYSTEM DESIGN (Continued)			
Tank orientation	Horizontal Vertical	Determines operating pressure at various locations.	Section 4.2
Pump location	Above-ground Submersible	Submersible pump failures cannot cause releases.	Section 4.7
Tank/pipe joint construction	Welded flanges Gaskets	Determines failure rate and mechanism.	Sections 4.4, 4.9
Emergency shut-off controls	Manual Automatic (manual back-up) Automatic only	Affects overflow probability.	Sections 3.3, 4.4
Operating procedures	Continuous Batch	Affects overflow probability, fill/discharge rates, and total daily fill/discharge time.	Sections 3.3, 4.4
Level Control system	Manual Automatic	Affects overflow probability.	Sections 3.3, 4.4
Number of batches per day (batch systems only)	Any	Determine the number of opportunities for tunities for start-up errors or overflows.	Section 4.4
Number of days before tank is emptied	1-365	Affects inventory detection threshold.	Section 4.12
Corrosion protection for tanks (carbon steel only)	Interior coating Exterior coating Interior and exterior coatings Cathodic protection with interior and/or exterior coatings No protection	Retards onset of corrosion.	Section 4.5

TABLE 10. USER INPUTS FOR HAZARDOUS WASTE TANK FAILURE MODEL (Continued)

Variable Description	Possible Choices	Effect	Cross References
SYSTEM DESIGN (Continued)			
Corrosion protection for piping (carbon steel only)	Interior coating Exterior coating Interior and exterior coating Cathodic protection Cathodic protection with interior and/or exterior coatings No protection	Regards onset of corrosion.	Section 4.6
ENVIRONMENTAL CHARACTERISTICS			
Geologic or weather-related hazards	Each of these variables may be set to true of false. They may be used in any combination.	Determines system vulnerability to external catastrophes.	Section 4.4
• Earthquake zone			
• Flood plain			
• Hurricane region			
• Tornado region			
Soil characteristics			
• pH	5.0 - 9.0	These variables all influence leak rates from underground leaks.	Section 4.5, 4.6
• Resistivity	50-50,000 ohm-cm		
• Presence of sulfides	Yes or No		
• Moisture content	Dry Damp Saturated		

TABLE 10. USER INPUTS FOR HAZARDOUS WASTE TANK FAILURE MODEL (Continued)

Variable Description	Possible Choices	Effect	Cross References
ENVIRONMENTAL CHARACTERISTICS (Continued)			
Backfill material	Clay Silt Sand Gravel	Influences leak rate from underground leaks.	Section 4.11
WASTE CHARACTERISTICS			
pH	2 to 9	Determines if environment is extreme or normal (cut-off is pH=3.5).	Section 4.4
Density	No limitations	Influences leak rate.	Section 4.11
Viscosity	No limitations	Influences leak rate.	Section 4.11
Ignitability	True or false	Determines if on-site fires or explosions are possible.	Section 4.4
Diffusivity in air	No limitations	Influences time lag for detection by vapor wells.	Section 4.12
Vapor pressure	No limitations	Influences time lag for detection by vapor wells.	Section 4.12

TABLE 10. USER INPUTS FOR HAZARDOUS WASTE TANK FAILURE MODEL (Continued)

Variable Description	Possible Choices	Effect	Cross References
SECONDARY CONTAINMENT			
Tank system	Concrete pad and curb Asphalt pad and curb Concrete vault Synthetic liner Concrete vault with synthetic liner Double-walled tank (with or without other secondary containment features) No secondary containment	As long as they are functioning, secondary containment systems prevent tank releases from reaching the environment.	Section 4.4
Pipe system	Asphalt pad (with earthen dikes or asphalt or concrete curbs) Concrete pad (with earthen dikes or asphalt or concrete curbs) Liner (with or without other forms of secondary containment) Double-walled piping (with or without other forms of secondary containment) No secondary containment	As long as they are functioning, secondary containment systems prevent pipe releases from reaching the environment.	Section 4.4
Maintenance level for pad and vault	Good Poor	Determines failure date of secondary containment component.	Section 4.4
Thickness of asphalt pad	2 to 6 inches	Determines failure date of asphalt pad	Section 4.4

TABLE 10. USER INPUTS FOR HAZARDOUS WASTE TANK FAILURE MODEL (Continued)

Variable Description	Possible Choices	Effect	Cross References
LEAK DETECTION SYSTEM			
Possible detection methods (may be used in any combination)	Visual inspection Inventory monitoring Tank integrity testing Pipe integrity testing Ultrasonic testing (tanks only) Interstitial monitoring for tanks and/or pipes (double-walled or lined tanks and pipes only). U-tubes Pollulert system Pipe monitoring Vapor wells Liquid sensor in vault No leak detection	Determines leak duration.	Section 4.12
Inspection frequency	Casual only Weekly Monthly	Determines leak duration.	Section 4.12
Inventory monitoring frequency	Weekly After any specified number of months	Determines leak duration.	Section 4.12
Inventory monitoring detection limit	Any specified % of throughput	Determines minimum leak rate which may be detected.	Section 4.12
Tank integrity testing frequency	Semi-annual Annual Every five years In any specified set of years (up to 10 years may be specified)	Determines leak duration.	Section 4.12

TABLE 10. USER INPUTS FOR HAZARDOUS WASTE TANK FAILURE MODEL (Continued)

Variable Description	Possible Choices	Effect	Cross References
LEAK DETECTION SYSTEM (Continued)			
Pipe integrity testing frequency	Semi-annual Annual Every five years In any specified set of years (up to 10 years may be specified)	Determines leak duration.	Section 4.12
Tank integrity testing limit	Any	Determines minimum leak rate which may be detected.	Section 4.12
Pipe integrity testing limit	Any	Determines minimum leak rate which may be detected.	Section 4.12
Pipe monitoring detection limit	Any	Determines minimum leak rate which may be detected.	Section 4.12
Ultrasonic testing frequency	In any specified set of years (up to 5 years may be specified)	Determines leak duration.	Section 4.12
Vapor well distance from pipes, pumps, and tank	Any non-zero distance	Determines lag until detection.	Section 4.12
Vapor well detection threshold	Any	Determines minimum leak rate which may be detected.	Section 4.12
Frequency of U-tube monitoring	Weekly Monthly Quarterly Annually	Determines leak duration.	Section 4.12

TABLE 10. USER INPUTS FOR HAZARDOUS WASTE TANK FAILURE MODEL (Continued)

Variable Description	Possible Choices	Effect	Cross References
SIMULATION CONTROL VARIABLES			
Number of iterations	Any	Larger numbers of iterations produce more accurate release profiles.	Section 4.2
Length of simulation period	1-40 years	Determines duration of simulation period.	Section 4.2
Initial age of tank population to be modeled	0-39 years	Determines stochastic characteristics of existing tank systems.	Section 4.2
Types of failures to be culled from existing tank population	Detected tank failures only Detected tank failures plus undetected tank failures All tank leaks and ruptures	Determines stochastic characteristics of existing tank systems.	Section 4.2

number of operating hours per day and operating days per week for treatment tanks.

Tank Dimensions. Tank dimensions are calculated according to the formulas presented in Table 11. These formulas are derived from the standard geometric formulas for the column of a cylinder. In deriving these formulas, we have assumed that each tank is 1.005 times larger than its rated capacity. In addition, we have used a fixed height-to-diameter ratio for each category of tanks. These height-to-diameter ratios are presented in the last column of the table, and are derived from tank dimension data obtained from Kirby (1979), Holzauer (1980), personal communications with an oil refining manager, and personal observations.

Steel and stainless steel tanks of less than 50,000-gallons capacity are horizontal or vertical cylinders with flat or ellipsoidal ends. These tanks have lengths (or heights) that are twice as large as their diameters. A 10,000-gallon tank is therefore 9.5 feet in diameter and 19 feet long. A 50,000-gallon tank is 16 feet in diameter and 32 feet long. Because the difference between flat and ellipsoidal ends is not significant, we have used a single formula for both shapes.

Steel and stainless steel tanks with capacities in excess of 50,000 gallons are always vertical and are not so elongated, having length-to-diameter ratios of 1. Thus, a 60,000-gallon tank is 22 feet in diameter and 22 feet high, while a 375,000-gallon tank is 40 feet in diameter and 40 feet high. For strength reasons, steel tanks are seldom more than 40 feet in height. Therefore, for tanks larger than 375,000 gallons, we have fixed the height at 40 feet and enlarged the diameter to include the the necessary volume.

Fiberglass tanks, on the other hand, are more elongated than even the smallest steel tanks, having lengths that are three times greater than their diameters. Because fiberglass is not as structurally strong as steel, these tanks are not extremely large. Based on Kirby (1978) and Holzauer (1980), we have chosen 30,000 gallons as a practical limit to the size of fiberglass tanks.

TABLE 11. DIMENSIONS FOR TANKS OF VARIOUS CAPACITIES AND CONSTRUCTION MATERIALS

Tank Material	Tank Capacity (gallons)	Tank Shape	Tank Diameter (feet)	Tank Length or Height (depending on orientation) (feet)
Steel or Stainless Steel[1,4]	$\leq$50,000	horizontal cylinder	$.440(1.005 \times \text{volume})^{1/3}$	2 x Diameter
	$\leq$50,000	vertical cylinder	$.440(1.005 \times \text{volume})^{1/3}$	2 x Diameter
	50,001 to 375,000	vertical cylinder	$.554(1.005 \times \text{volume})^{1/3}$	1 x Diameter
	>375,000	vertical cylinder	$.0652(1.005 \times \text{volume})^{1/2}$	40 feet
Fiberglass Reinforced Plastic (FRP)	$\leq$ 30,000	horizontal cylinder	$.385(1.005 \times \text{volume})^{1/3}$	3 x Diameter
	$\leq$ 30,000	vertical cylinder	$.385(1.005 \times \text{volume})^{1/3}$	3 x Diameter
Concrete[2,4]	any	vertical cylinder	$.698(1.005 \times \text{volume})^{1/3}$	1/2 x Diameter
		rectangular	$.406(1.005 \times \text{volume})^{1/3}$ (gives both length and height)	2 x Width (gives tank length)

Sources: [1] Holzauer (1980).
[2] SCS Engineers (Estimated Cost of Compliance (1984)).
[3] Kirby (1978).
[4] PRA estimates based on personal observations and conversations with oil refinery managers.

Concrete tanks may be any size and may be either cylindrical or rectangular. Cylindrical tanks are always vertical, with heights that are only 50% of their diameters. Rectangular tanks are always horizontal, with length, width, and height having ratios of 2:1:1, respectively. Unlike steel tanks, concrete tanks may exceed 40 feet in height.

Tank Thickness. Tank wall-thicknesses are selected to give the tank the necessary structural strength. For steel and stainless steel tanks, these thicknesses also include a standardized corrosion allowance. Table 12 presents the standard tank wall-thicknesses for steel, stainless steel, and concrete tanks of various capacities. For steel and stainless steel tanks, these thicknesses range from .25" to .625". For concrete, they range from 6" to 15". We use these wall-thicknesses to calculate dates of corrosion failure (for steel tanks) and rates of fluid seepage through the pores of concrete tanks. These calculations will be described in Section 4.5 below. Tank wall-thickness does not influence our estimated probability of rupture, however. Instead, we assume that the tank is designed to have a sufficient safety margin against normal operating stresses. Larger tanks have stronger walls, but they also experience greater stresses. We assume that these two factors cancel out and that tank rupture probabilities are therefore independent of tank size.

Component Specifications and System Layout. The choices of tank capacity, tank orientation, throughput, tank location, and the process for which the tank is being used serve to specify a number of other design parameters. These parameters include the average depth of the fluid in the tank, the identity of the fluid contained in each tank or pipe, the number and operating pressures of the pumps, the diameter of the pipes, and the relative elevations of pipes, fill tanks, and process or storage tanks.

These parameters influence two important aspects of the model: they determine the operating pressure in each component, and they determine the fraction of the time when each of the pipes and ancillary components are in use. The operating pressures determine leak rates (see Section 4.11 below) while the periods of operation determine the fraction of the

TABLE 12. TANK WALL THICKNESSES

Tank Material	Tank Capacity (gallons)	Tank Wall Thickness (inches)
Steel and Stainless Steel[1]	<10,000	0.25
	10,001 - 20,000	0.31
	20,001 - 30,000	0.38
	30,001 - 100,000	0.50
	>100,000	0.625
Concrete[2]	<3,000	6
	3,001 - 20,000	8
	20,001 - 50,000	12
	>50,000	15

Sources:

[1] Holzauer (1980).

[2] SCS Engineers, Estimated Cost of Compliance 1984).

operating day during which leakage can occur, and determine the amount of wear and tear on pumps, valves, and other ancillary equipment.

It is impractical for the main body of this report to present the details of the calculation of operating pressures and periods of ancillary equipment operation. Because the model includes so many design options, it allows hundreds of different combinations of operating pressures and operating periods. The effect of each design option on these parameters is explained in Appendix D.

Environmental characteristics.

The model allows us to vary environmental parameters. Some of these parameters identify which geologic or weather-related hazards may threaten a particular locale. Other environmental variables allow us to specify the soil pH, resistivity, and moisture content at a particular site and to determine whether or not the soil contains sulfides. These soil characteristics determine the corrositivity of the soil; their effects will be described in Section 4.5, below.

Waste Characteristics

The model also allows us to vary the physical and chemical characteristics of the waste stream. These characteristics determine leak rates from above- and below-ground holes, influence the detection lags for various leak detection methods, and determine whether or not the waste is flammable. The effects of these variables are listed in Table 10; more detailed information may be obtained from the sections of this report listed there as cross references.

Secondary Containment and Leak Detection.

Two other classes of variables allow us to specify the design of the facility's secondary-containment and leak-detection systems. Table 10 lists the options for each of these systems, as well as the parameters affecting their performances. These systems and the effects of the listed parameters will be described in detail later in this report.

Simulation Control Variables

The final category of user inputs for the Monte Carlo model are the simulation control variables. These four variables allow us to control the number of iterations, set the length of the simulation period, set the initial facility age when existing tanks are being modeled, and determine the rules for culling existing tanks that have already failed before the start of the simulation period.

Number of Iterations. The number of iterations determines the accuracy of the release profiles produced by the model. A large number of iterations provides a more representative sample, and smooths out the effects of any particularly unusual results. In addition, a large number of iterations allows rare events to occur, so that the composite release profile more closely represents the entire range of possible performances.

Generally, 500 to 1000 iterations are recommended for simple Monte Carlo models (EPA, Liner Location Report, Appendix A, 1984). Because of budget constraints, however, complex models such as ours are often run with 200 or fewer iterations (EPA, Liner Location Report, Appendix A, 1984). For such models, their lengthy time horizons effectively increase the number of iterations by repeating major portions of the model once each simulation period. Thus, 200 iterations of a 30-year model serve to simulate 6000 operating years, or 72,000 operating months, thus providing opportunities for many different events to occur.

Length of Simulation period. Our model allows us to specify any simulation period between 1 and 40 years. In principal, the model could accomodate longer simulations, but few tank systems last that long, and there is almost no data on the performance of those that do.

Initial Age of Tank Facility and Culling Rules. The Monte Carlo model is capable of simulating either new or existing facilities. To simulate new facilities, we specify an initial age of zero. To simulate existing facilities we begin by specifying the age of the facilities to be modeled and the rule to be used to cull leaking tanks from the year-zero population. A simple example best illustrates how these two parameters work. Suppose that we wish to model 5-year-old storage tanks over a 20-year simulation period. For each iteration, the model first runs a 5-year simulation in order to determine the random processes that have already occurred before the start of the simulation period. If the tank fails within that period, the model uses the culling rule to determine whether the iteration should be continued. The purpose of the culling rule is to determine which types of presently leaking tanks we wish to include in the simulation. Tanks with detected leaks, for example, will have been replaced at least once, and we should no longer classify them as 5-year-old tanks. Similarly, if tightness testing is to be required as a condition for the granting of permits, we may wish to also cull tanks with previously undetected tank leaks, for they will be replaced at the time of testing. Using the options listed in Table 10, we can cull only iterations which have had detected tank failures, those which have had either detected or undetected tank failures, or those which have had leaks or ruptures in any system component. Iterations that are not culled before year 5 then continue through an additional 20-year simulation in order to predict their future performances. Thus, for those iterations which are not culled, the simulation process covers a total time period of 25 years.

We can use this technique to simulate existing tanks of any desired age, but because of the limitations on our failure data, the total modeled time period cannot exceed 40 years.

4.3 Probability Sampling

Once the system parameters have been chosen, the Monte Carlo simulation model begins to evaluate the fault trees. The basic element of this process is the simulation of individual stochastic events by a procedure referred to as "event sampling." Event sampling consists of the use of computer-generated random numbers to determine whether any of the stochastic events have occurred. There are two approaches to event sampling: binomial sampling and time-to-failure sampling. In binomial sampling, the computer selects a random number between 0 and 1 and compares that number to the event's probability. If the random number is less than or equal to the probability, then the event is declared to have occurred. Otherwise, it does not occur. In this way, the Monte Carlo model ensures that each binomial event occurs with the probability assigned to it.

In our model, binomial sampling may occur monthly, annually, or on a per demand basis. Monthly sampling is capable of detecting up to 12 occurrences per year (one per month). Annual sampling, however, can detect no more than one occurrence per year; the month of occurrence can be determined by drawing an additional random number between 0 and 12. Annual sampling requires less computer time because it uses at most two random numbers per year (monthly sampling uses 12), but is less accurate because it fails to detect repetitions of the same event during a single year. In order to compromise between computer costs and model accuracy, we have generally used annual sampling only when the annual probability is less than 3%. Under these circumstances, the probability of multiple occurrences is less than .09% (3% x 3%), which is insignificant compared to the uncertainty likely to be inherent in the original estimate.

In addition to being annual or monthly, binomial probabilities can also be specified on a per-demand basis. Per-demand probabilities give the likelihood of failure on each occasion that a component is needed. Thus, we often use per-demand probabilities when the component is part of an emergency back-up system. For such systems, it is much more useful to know the probability that a component fails when it is needed than it is to know the probability that it fails during any given month or year. Furthermore, by using per-demand probabilities for such components, we save considerable computer time, for then these events need only be sampled when the back-up systems are required.

It is possible to model any stochastic event using only binomial sampling, but time-to-failure sampling is more convenient for events for which cumulative time-to-failure probabilities are easily computed.

A cumulative time-to-failure probability is simply the probability that the failure event in question has occurred at or before a given time. A set of such cumulative probabilities is a cumulative time-to-failure distribution. An example is given in the following table:

Year	Cumulative Probability
1	.05
2	.10
3	.20
4	.60
5	1.00

This distribution means that there is a 5% probability that the event has occurred by the end of year 1, a 10% probability that it has occurred by the end of year 2, a 20% probability that it has occurred by the end of year 3, etc. This is equivalent to saying that there is a 5% probability the event occurs in year 1, a 5% probability that it occurs in year 2, and a 10% probability that it occurs in year 3. In this example, the event will occur with certainty by the end of year 5.

In time-to-failure sampling, the computer selects a random number between 0 and 1 and determines the date of failure by comparing that number to the cumulative probability distribution. In the above example, a random number of .4 would mean that the event occurs during year 3.

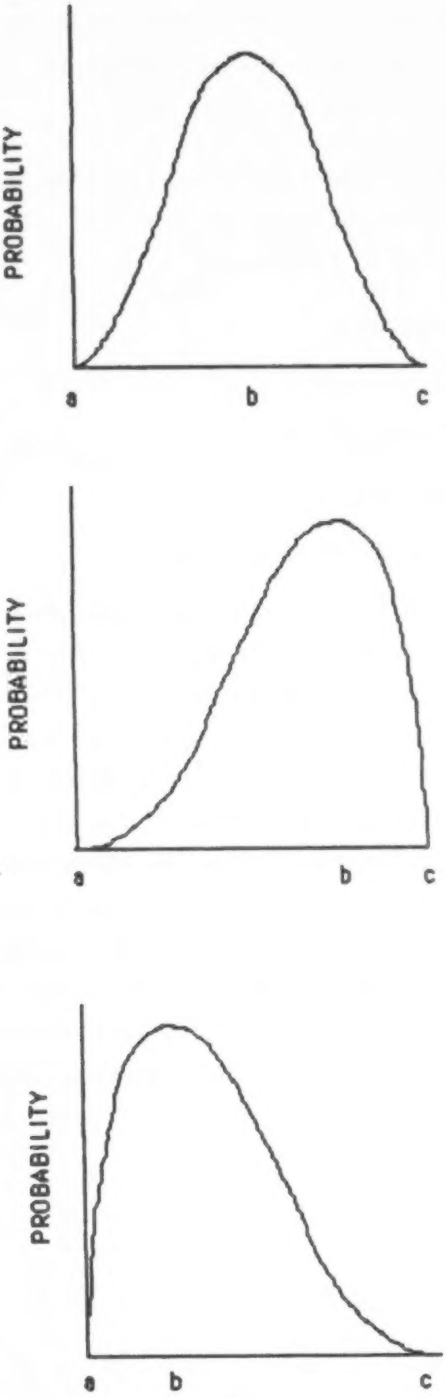
Binomial and time-to-failure sampling provide comparable but slightly different information. Binomial sampling reveals whether or not the sampled event occurs during any given time period; the sampling process must therefore be repeated regularly until the event occurrs. Time-to-failure sampling, on the other hand, need only be done once per component. The computer then remembers the date of failure, periodically compares the component age to its failure date, and determines whether or not the component has failed yet. Under either sampling technique, once the component fails it remains in its failed state until the failure is detected and repaired. At that time, the model assumes that the component is restored to an as-new condition, and the computer resumes the sampling process with the repaired component's age re-set to zero.

Our computer model uses time-to-failure sampling whenever a cumulative probability distribution is assigned to an event. These probability distributions fall into five basic categories:

- Normal distributions,
- Uniform distributions,
- Empirical distributions,
- Beta distributions, and
- Conditional normal distributions.

The first four of these distributions are easy to describe. The normal distribution is usually represented by the familiar bell-shaped curve; its cumulative distribution is mathematically specified by its mean and standard deviation. A uniform distribution occurs when there is an equal chance of failure for any of a range of dates; its time-to-failure distribution is mathematically specified by the end points of that range. An empirical distribution is a distribution similar to the hypothetical distribution used above; its cumulative distribution is given as a series of dates and cumulative probabilities. A beta distribution looks somewhat like a skewed, truncated normal, with its peak shifted either to the right or the left. Examples are depicted in Figure 18. The beta distribution is completely specified by three values, the minimum, maximum, and mode (peak). Its cumulative distribution can also be obtained from these values.

FIGURE 18. BETA DISTRIBUTIONS



The final distribution used by our model is the conditional normal. This distribution is a combination of a binomial and a normal distribution. The binomial distribution is sampled once (in year 1) to determine whether failure occurs. If the response is positive, the normal distribution is then sampled to determine when the failure takes place. A conditional normal distribution therefore combines two random processes into a single probability distribution. One process is the binomial occurrence of the initiating event, the other is the (normal) determination of the date of failure.

In order to refer to these distributions conveniently, we have developed a shorthand notation for each of the five parametric distributions. These notations, which will be used throughout the remainder of this report, are:

- p = a (binomial distribution with probability a);
- N(x,y) (normal distribution with a mean of x and a standard deviation of y);
- FNU(a,b) (uniform distribution between values a and b);
- B(a,b,c) (beta distributions with minimum a, mode b, and maximum c); and
- pN(X,y) (conditional normal with binomial probability p and normal time-to-failure N(x,y)).

Empirical distributions will be described by a table of their cumulative probabilities.

4.4 Fault Tree Event Probabilities

We used a combination of engineering judgment, published failure data, and conversations with equipment vendors to assign probability distributions to each of the basic events in the fault trees in Chapter 2. Where possible, we drew our probability values directly from the most reliable published sources. In many cases, however, the available data were not directly applicable, and had to be modified to fit the events being modeled. Sometimes such modifications were required because failure data were not available for the proper component; on other occasions modifications were required in order to adjust the published failure rates to apply to the appropriate operating conditions.

Because of the number of events and the complexity of some of the derivations, it is impractical to discuss all of them in the main body of this report. Instead we have listed the probabilities in Table 13, and have presented the details of the derivations in Appendix A.

Many of the probabilities presented in Table 13 are dependent on system design characteristics. These probabilities have therefore been included in Table 13 as general formulas. These formulas use the following variables as inputs:

A = the surface area of the component.

H_d = the number of operating hours in a day. For storage tanks, H_d is the number of hours required to transfer a batch of waste from the collection tank to the storage tank. I.e., for the purposes of formulas using H_d, we only consider a storage tank to be "operating" when it is being filled.

H_m = the number of operating days per month. For storage tanks, H_m is the number of transfers per month. Thus, for storage tanks, $H_m = 30n_b$.

j = the number of pump-outs per year. (This parameter only applies to storage or accumulation tanks).

n_b = the number of batches per day. For storage tanks, n_b may be less than 1.

T_b = the time it takes to transfer one batch into the tank (in hours). For continuous sytems, $T_b = H_d$.

T_p = the time it takes to pump-out the tank (in hours). (This parameter only applies to storage or accumulation tanks).

The events in Table 13 are grouped into 9 categories:

- Corrosion,
- Ruptures,
- Installation damage,
- Control equipment failures,

TABLE 13. BASIC EVENT PROBABILITIES

Type of Failure and Event Label[1]	Probability[2]
CORROSION	
Tanks (T1121, T1123, T1125, T1127, T1128)	See Section 4.5
Pipes (B13)	See Section 4.6
Pumps (A2116)	See Section 4.7
Gaskets (B122)	See Section 4.9
Erosion (B13, A2116)	See Section 4.10
RUPTURES	
Tanks (above-, below-, or in-ground)	
• Steel (T1124)	5.3×10^{-3}/yr
• Stainless steel (T1124)	5.3×10^{-3}/yr
• Fiberglass (T1124)	1.06×10^{-2}/yr
• Concrete (B41)	N (35,10)
• Double-walled tanks (T1124)	
- inner wall	2.6×10^{-3}/yr
- outer wall	5.3×10^{-3}/yr
- conditional probability that outer wall breach also breaches inner wall	50%
Pipes (above- or below-ground)	
• Steel (B11)	3×10^{-3}/yr
• Stainless steel (B11)	3×10^{-3} /yr
• Fiberglass (B11)	6×10^{-3}/yr
• Double-walled pipes (B13)	
- inner wall	1.5×10^{-3}/yr
- outer wall	3×10^{-3}/yr
- conditional probability that outer wall breach also breaches inner wall	50%
Flange leaks (B121)	5×10^{-3}/yr

TABLE 13. BASIC EVENT PROBABILITIES (Continued)

Type of Failure and Event Label[1]	Probability[2]
INSTALLATION DAMAGE (or damage during shipping)	
Tank (below-, above-, or in-ground) (LIFDEF (I,5)A)	
• Steel	.03/tank
• Stainless steel	.03/tank
• Fiberglass	.04/tank
• Concrete	.03/tank
Pipe (below- or above-ground) (LIFDEF (I,5)B or LIFDEF (I,5)C)	
• Steel	.01/pipe
• Stainless steel	.01/pipe
• Fiberglass	.02/pipe
Welded flange (LIFDEF (I,5,D)	.02/flange
Gasket (LIFDEF (I,5)E)	.015/gasket
CONTROL EQUIPMENT	
Automatic level controller fails (FLVCN1)	.094/mo
Level indicator fails (MOLEVIN)	.16/mo
Mechanical failure of automatic inlet valve	
• normal environment ($pH > 4.5$)[3] (OPVLON)	$1-(1 - 3.4 \times 10^{-5})H_dH_m$
• extreme environment ($pH \leq 4.5$)[3] (OPVLOE)	$1-(1 - 3.4 \times 10^{-4})H_dH_m$
Tank is being filled when nearly full (MOFILL)	
• Storage or accumulation tanks	.079/mo
• Treatment tanks	1.00/batch

TABLE 13. BASIC EVENT PROBABILITIES (Continued)

Type of Failure and Event Label[1]	Probability[2]
EMERGENCY SHUT-OFF EQUIPMENT	
High level alarm fails (MOALARM)	.1/demand
High level sensor fails (LEVIN2)	.008/demand
Microprocessor fails (FLVCN2)	.05/demand
Inlet pump fails to shut off	
• Normal environment ($pH > 4.5$)[3] (MOPMON)	$7.5(T_b) \times 10^{-7}$/demand
• Extreme environment ($pH \leq 4.5$)[3] (MOPMDE)	$7.5(T_b) \times 10^{-5}$/demand
Inlet valve sticks in open position	
• Normal environment ($pH > 4.5$)[3] (MOVLOE)	$3.4(T_b) \times 10^{-5}$/demand
• Extreme environment ($pH \leq 4.5$)[3] (MOVLON)	$3.4(T_b) \times 10^{-4}$/demand
Outlet pump fails to open	
• Normal environment ($pH > 4.5$)[3] (MOPMCN)	$2(T_b) \times 10^{-6}$/demand
• Extreme environment ($pH \leq 4.5$)[3] (MOPMCE)	$2(T_b) \times 10^{-4}$/demand
Outlet valve fails to open	
• Normal environment ($pH > 4.5$)[3] (MOVLCN)	$3.4(T_b) \times 10^{-5}$/demand
• Extreme environment ($pH \leq 4.5$)[3] (MOVLLE)	$3.4(T_b) \times 10^{-4}$/demand
HUMAN ERRORS	
Failure to detect improper installation or shipping damage (LIFDEF(I,3))	
• No inspection	1.00/demand
• Visual inspection	.50/demand
• Visual inspection and weld testing	.25/demand
• Visual inspection, weld testing, and tightness testing	.05/demand
Operator throws wrong switch, etc. in response to an alarm (OFTRCOM)	3×10^{-3}/demand

TABLE 13. BASIC EVENT PROBABILITIES (Continued)

Type of Failure and Event Label[1]	Probability[2]
HUMAN ERRORS (Continued)	
Operator fails to act in response to an alarm (OFTROM)	3×10^{-2}/demand
Operator control error causes attempted overfill (OPCOMM)	
• Batch systems	$1-(.914)^{n_b}$/month
• Continuous systems	.086/mo
SECONDARY CONTAINMENT FAILURES	
Asphalt pad cracks (B21)	
≤2.5" pad, no maintenance	B(2.5,8,12)
≤2.5" pad, with maintenance	B(4,12,15)
>2.5" pad, no maintenance	B(4,12,15)
>2.5" pad, with maintenance	B(5,15,18)
Asphalt-covered berm (B21)	
≤2.5" thickness of asphalt, no maintenance	B(2.5,8,12)
≤2.5" thickness of asphalt, with maintenance	B(4,12,15)
>2.5" thickness of asphalt, no maintenance	B(4,12,15)
>2.5" thickness of asphalt, with maintenance	B(5,15,18)
Concrete pad develops cracks (B31)	N(30,5)
Concrete curb develops cracks (B33)	N(30,5)
Concrete vault develops cracks (B41)	N(35,10)
Synthetic liner fails (B51)	N(35,10)

TABLE 13. BASIC EVENT PROBABILITIES (Continued)

Type of Failure and Event Label[1]	Probability[2]
EXTERNAL CATASTROPHES	
Vandalism (ANUCAT (I,2))	1×10^{-6}/yr
Damage due to earthquake (ANUCAT (I,4))	8×10^{-4}/yr
Tornado damage (ANUCAT(I,3))	1.5×10^{-4}/yr
Hurricane damage (ANUCAT (I,3))	1.4×10^{-2}/yr
Damaging flood (ANUCAT (I,5))	5×10^{-3}/yr
Ignitable waste catches fire	1×10^{-6}/yr
Nearby fire or explosion (ANUCAT (I,7))	
• above- or in-ground system	3×10^{-3}/yr
• below-ground system	1×10^{-3}/yr
ACCIDENTAL SPILLS	
Strainer Drain Left Open After Maintenance	
• On-site strainer (A11111)	.01/mo
• Strainer on pump-out truck (A11111)	$6(j) \times 10^{-5}$/yr
Pump Drain Left Open After Maintenance	
• On-site pump (A11112)	.01/yr
• Pump on pump-out truck (A11112)	$5(j) \times 10^{-6}$/yr
Flexible hose ruptures (A1112)	$5(j)(Tp) \times 10^{-3}$/yr
Loose flexible hose connection (A1115)	$j \times 10^{-2}$/yr

---

[1] These labels correspond to the labels in the fault trees. They are also used in Appendix A. That Appendix explains the derivation of each of these probabilities. It also lists the sources used in these derivations.

[2] The notation used for these probability distributions is explained in Section 4.3 of this report. The variables used in these formulas are defined in Section 4.4.

3 We have chosen a pH of 4.5 as the cut-off between normal and extreme environments (Perry and Chilton, 1973, p. 23-4). Highly alkaline environments will also be extreme, but the present version of our model does not include caustic wastes.

- Emergency shut-off failures,
- Human errors,
- Secondary containment failures,
- External catastrophes, and
- Accidental spills.

These events correspond to the basic events in the fault trees in Chapter 2. To allow easy reference to the fault trees, Table 13 includes the label for each of the events. These labels are also useful in locating the derivations of these probabilities in Appendix A.

In addition to listing the event probabilities in Table 13, we have constructed Figures 19 through 23 to illustrate how these probabilities may be integrated into the fault trees. Because it is impractical to incorporate all of the design-dependent probabilities into a single fault tree, Figures 19 through 23 are merely an example based on a specific system design. Furthermore, since some probabilities (particularly those influencing corrosion) vary with component age, these sample fault trees represent only one model year; in this example, we assume that the facility is 10 years old.

The facility modeled in Figures 19 through 23 has the following design characteristics:

- It is used for 180-day storage.
- The tank and piping are below-ground and are constructed of unprotected carbon steel, without secondary containment.
- Filling is done in once-a-day batches by gravity feed from an off-site collection tank. The gravity-feed system has manual level controls and manual emergency shut-off.
- The tank is emptied using a flexible hose and a pump on the pump-out truck. Pump-out takes 2 hours.
- The tank has a capacity of 5,000 gallons.
- There are two pipes: a 100-foot, 2"-diameter, fill pipe, and a 10-foot, 4"-diameter, pump-out pipe.

FIGURE 19. BASIC FAULT TREE FOR A 5000-GALLON UNDERGROUND STORAGE TANK

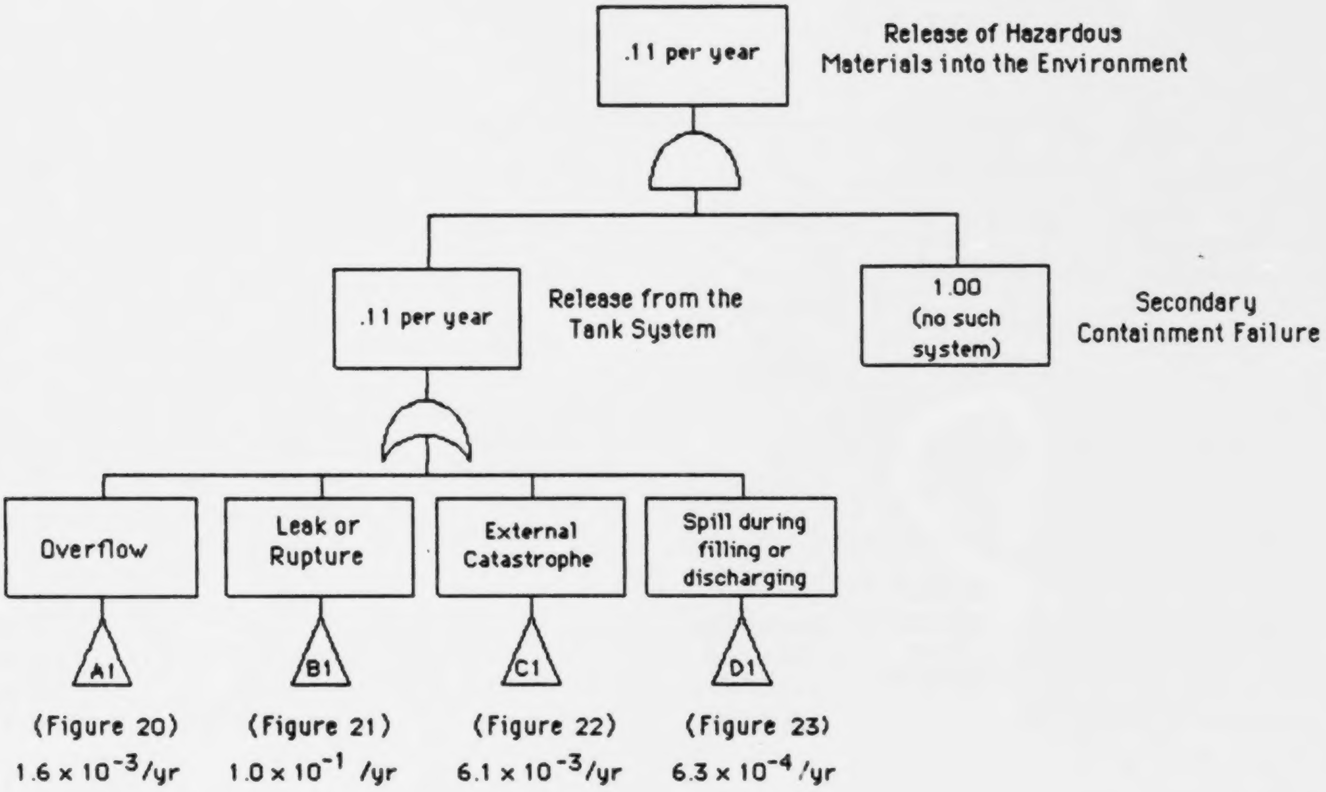
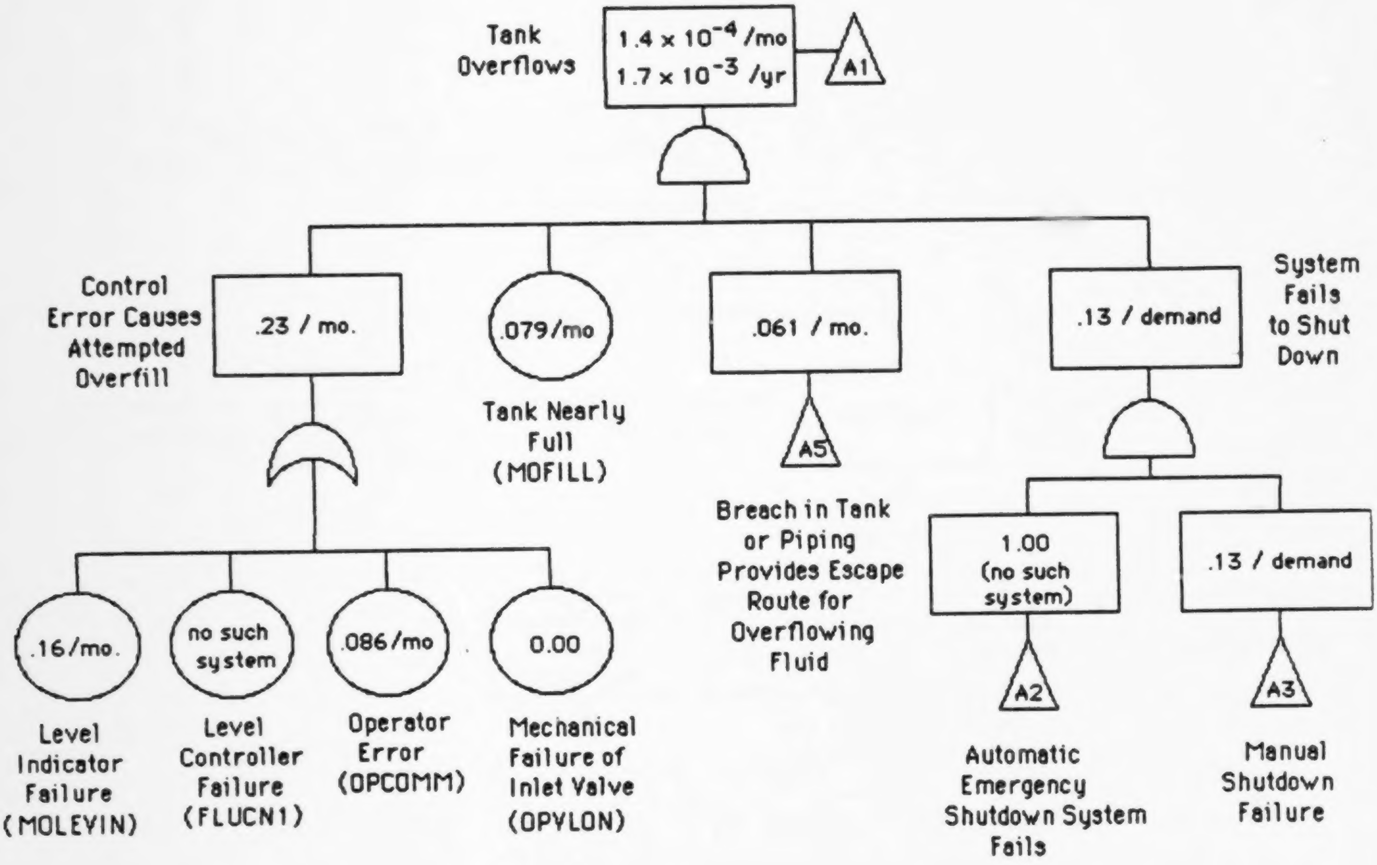

.11 per year
Release of Hazardous Materials into the Environment
.11 per year
Release from the Tank System
1.00 (no such system)
Secondary Containment Failure
Overflow
Leak or Rupture
External Catastrophe
Spill during filling or discharging
A1
B1
C1
D1
(Figure 20)
1.6 x 10-3/yr
(Figure 21)
1.0 x 10-1 /yr
(Figure 22)
6.1 x 10-3/yr
(Figure 23)
6.3 x 10-4 /yr

FIGURE 20A. OVERFLOWS FOR A 5000-GALLON UNDERGROUND STORAGE TANK



Tank Overflows
1.4 x 10⁻⁴ /mo
1.7 x 10⁻³ /yr
A1
Control Error Causes Attempted Overfill
.23 / mo.
.079/mo
Tank Nearly Full (MOFILL)
.061 / mo.
A5
Breach in Tank or Piping Provides Escape Route for Overflowing Fluid
.13 / demand
System Fails to Shut Down
.16/mo.
Level Indicator Failure (MOLEVIN)
no such system
Level Controller Failure (FLUCN1)
.086/mo
Operator Error (OPCOMM)
0.00
Mechanical Failure of Inlet Valve (OPVLON)
1.00 (no such system)
A2
Automatic Emergency Shutdown System Fails
.13 / demand
A3
Manual Shutdown Failure

FIGURE 20B. OVERFLOWS FOR A 5000-GALLON UNDERGROUND STORAGE TANK (cont.)

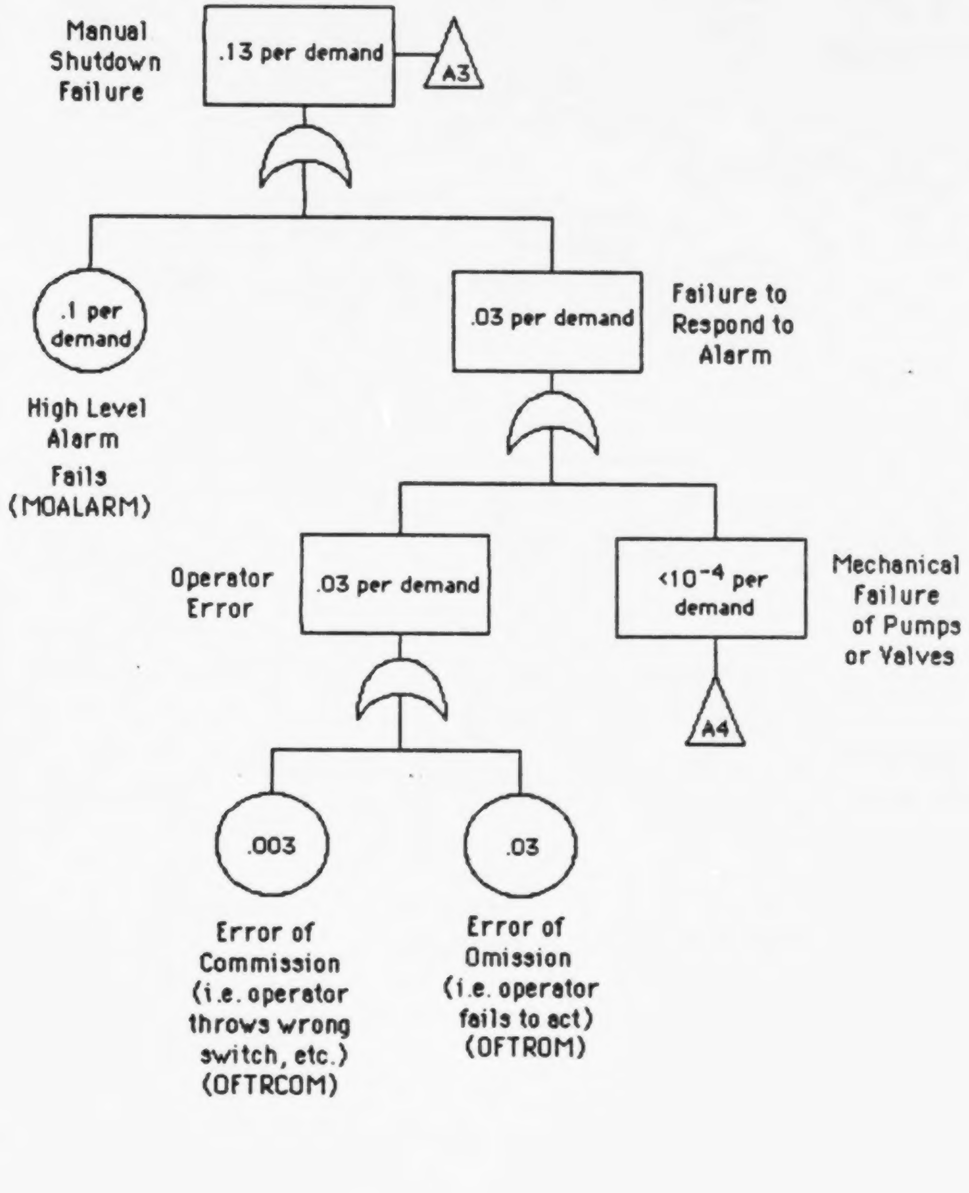

Manual Shutdown Failure
.13 per demand
A3
.1 per demand
High Level Alarm Fails (MOALARM)
.03 per demand
Failure to Respond to Alarm
Operator Error
.03 per demand
<10⁻⁴ per demand
Mechanical Failure of Pumps or Valves
A4
.003
.03
Error of Commission (i.e. operator throws wrong switch, etc.) (OFTRCOM)
Error of Omission (i.e. operator fails to act) (OFTROM)

FIGURE 20C. OVERFLOWS FOR A 5000-GALLON UNDERGROUND STORAGE TANK (cont.)

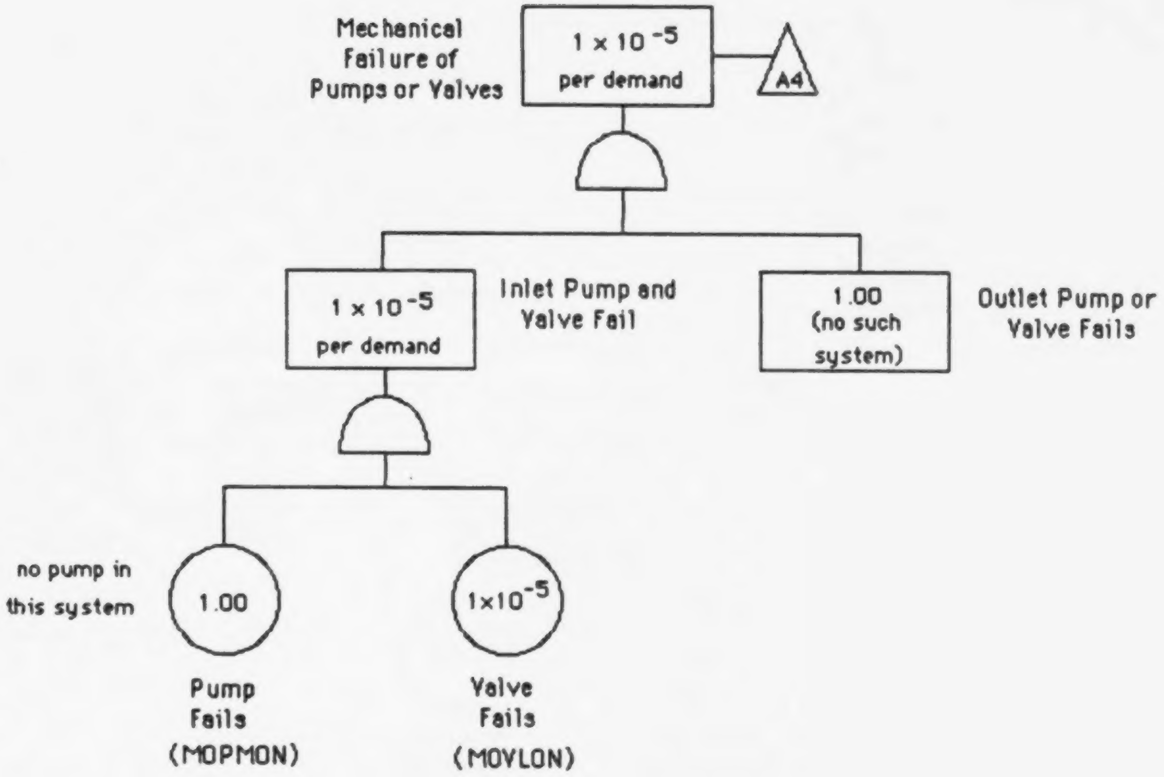
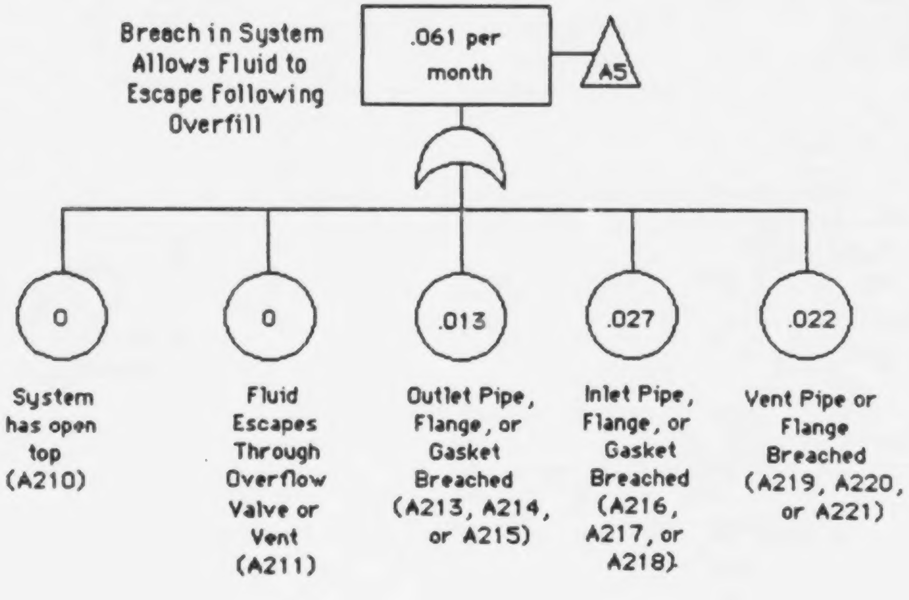
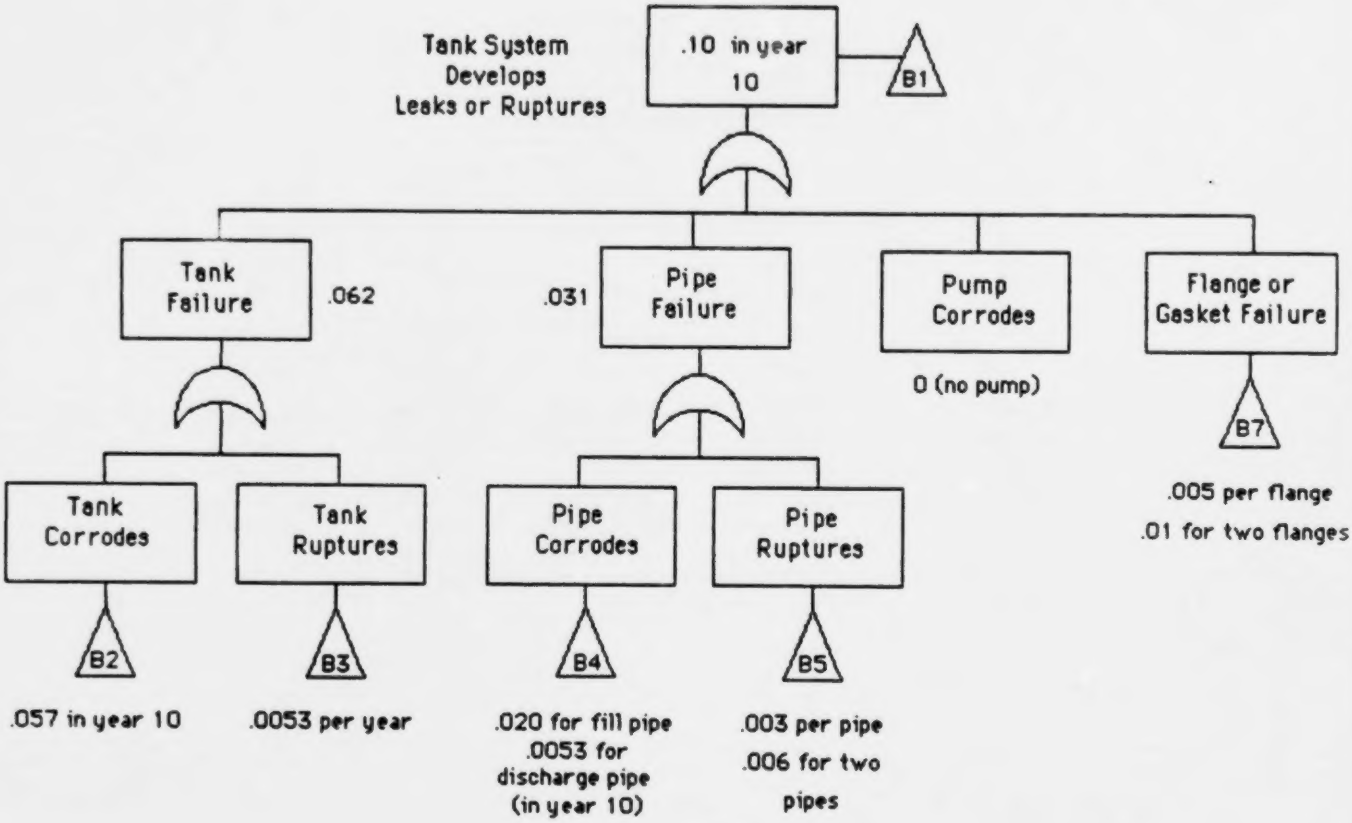

Mechanical Failure of Pumps or Valves
1 x 10 $^{-5}$ per demand
A4
1 x 10 $^{-5}$ per demand
Inlet Pump and Valve Fail
1.00 (no such system)
Outlet Pump or Valve Fails
no pump in this system
1.00
1x10^{-5}
Pump Fails (MOPMON)
Valve Fails (MOVLON)

FIGURE 20D. OVERFLOWS FOR A 5000-GALLON UNDERGROUND STORAGE TANK (cont.)



Breach in System Allows Fluid to Escape Following Overfill
.061 per month
A5
0
0
.013
.027
.022
System has open top (A210)
Fluid Escapes Through Overflow Valve or Vent (A211)
Outlet Pipe, Flange, or Gasket Breached (A213, A214, or A215)
Inlet Pipe, Flange, or Gasket Breached (A216, A217, or A218)
Vent Pipe or Flange Breached (A219, A220, or A221)

FIGURE 21A. LEAKS AND RUPTURES FOR A 5000-GALLON UNDERGROUND STORAGE TANK



Tank System Develops Leaks or Ruptures
.10 in year 10
B1
Tank Failure
.062
.031
Pipe Failure
Pump Corrodes
0 (no pump)
Flange or Gasket Failure
B7
.005 per flange
.01 for two flanges
Tank Corrodes
Tank Ruptures
Pipe Corrodes
Pipe Ruptures
B2
B3
B4
B5
.057 in year 10
.0053 per year
.020 for fill pipe
.0053 for discharge pipe (in year 10)
.003 per pipe
.006 for two pipes

FIGURE 21B. LEAKS AND RUPTURES FOR A 5000-GALLON UNDERGROUND STORAGE TANK (cont.)

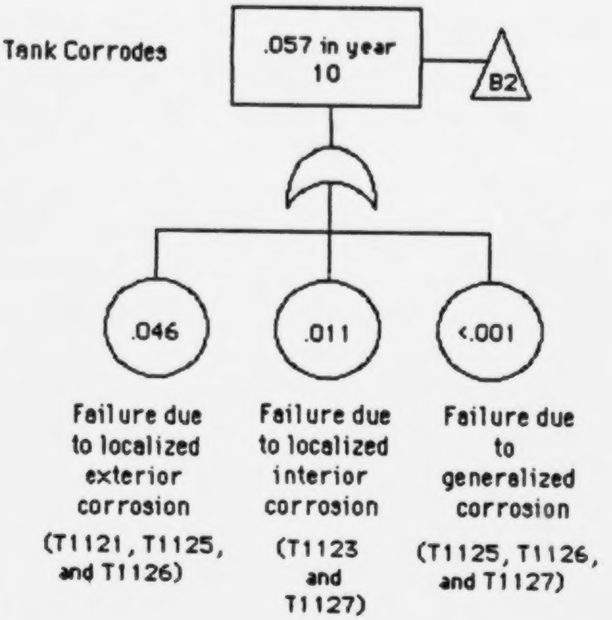

Tank Corrodes
.057 in year 10
B2
.046
.011
<.001
Failure due to localized exterior corrosion
(T1121, T1125, and T1126)
Failure due to localized interior corrosion
(T1123 and T1127)
Failure due to generalized corrosion
(T1125, T1126, and T1127)

FIGURE 21C. LEAKS AND RUPTURES FOR A 5000-GALLON UNDERGROUND STORAGE TANK (cont.)

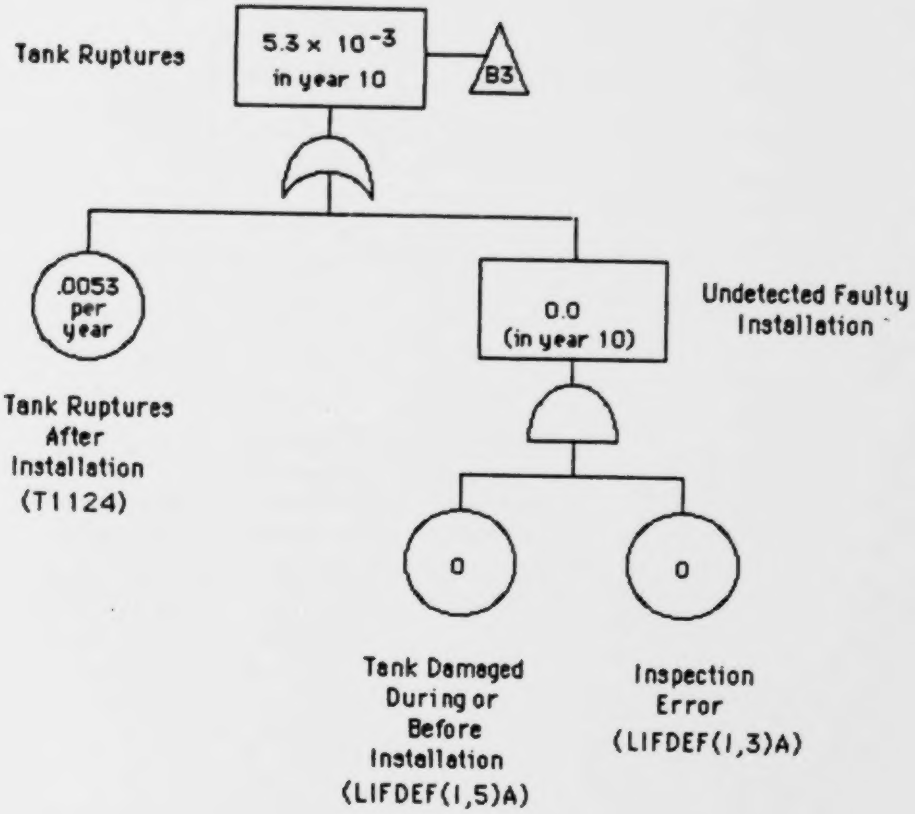

Tank Ruptures
5.3×10^{-3} in year 10
B3
.0053 per year
Tank Ruptures After Installation (T1124)
0.0 (in year 10)
Undetected Faulty Installation
0
0
Tank Damaged During or Before Installation (LIFDEF(1,5)A)
Inspection Error (LIFDEF(1,3)A)

FIGURE 21D. LEAKS AND RUPTURES FOR A 5000-GALLON UNDERGROUND STORAGE TANK (cont.)

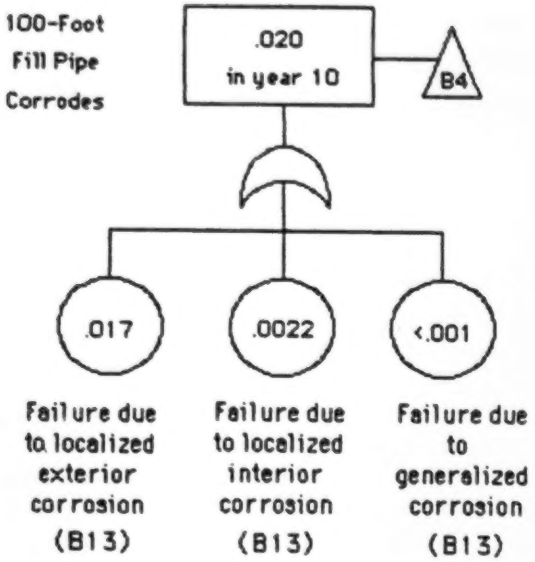

100-Foot
Fill Pipe
Corrodes
.020
in year 10
B4
.017
.0022
<.001
Failure due to localized exterior corrosion
(B13)
Failure due to localized interior corrosion
(B13)
Failure due to generalized corrosion
(B13)

FIGURE 21E. LEAKS AND RUPTURES FOR A 5000-GALLON UNDERGROUND STORAGE TANK (cont.)

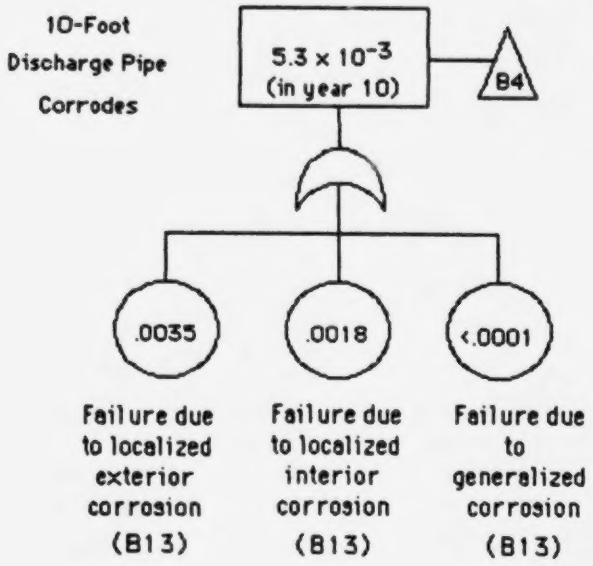

10-Foot Discharge Pipe Corrodes
5.3 x 10⁻³ (in year 10)
B4
.0035
.0018
<.0001
Failure due to localized exterior corrosion (B13)
Failure due to localized interior corrosion (B13)
Failure due to generalized corrosion (B13)

FIGURE 21F. LEAKS AND RUPTURES FOR A 5000-GALLON UNDERGROUND STORAGE TANK (cont.)

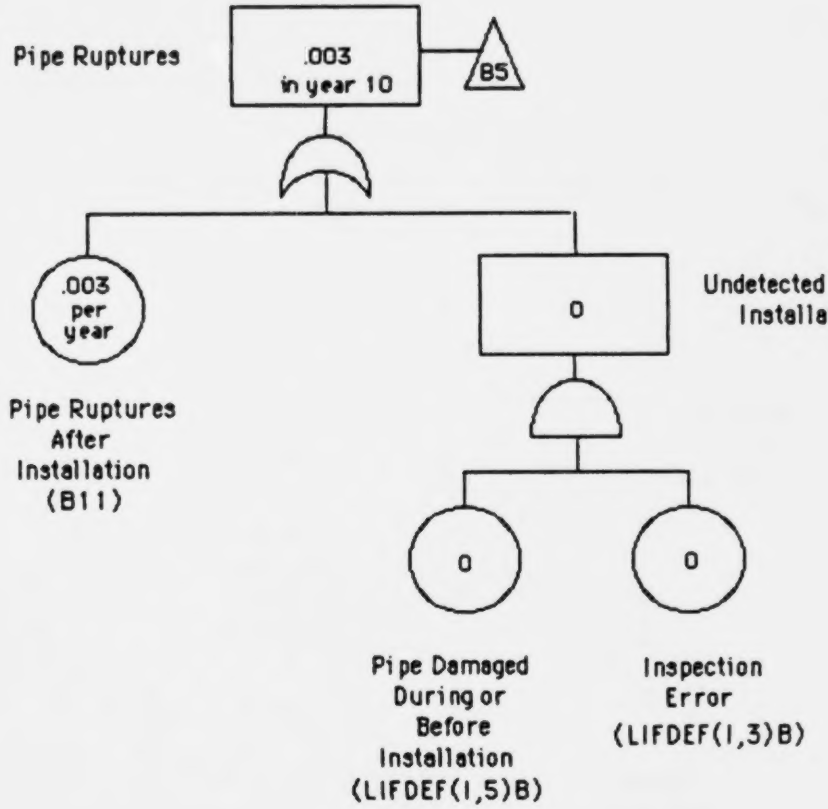

Pipe Ruptures
.003
in year 10
B5
.003
per
year
Pipe Ruptures
After
Installation
(B11)
0
Undetected Faulty
Installation
0
0
Pipe Damaged
During or
Before
Installation
(LIFDEF(1,5)B)
Inspection
Error
(LIFDEF(1,3)B)

FIGURE 21G. LEAKS AND RUPTURES FOR A 5000-GALLON UNDERGROUND STORAGE TANK (cont.)

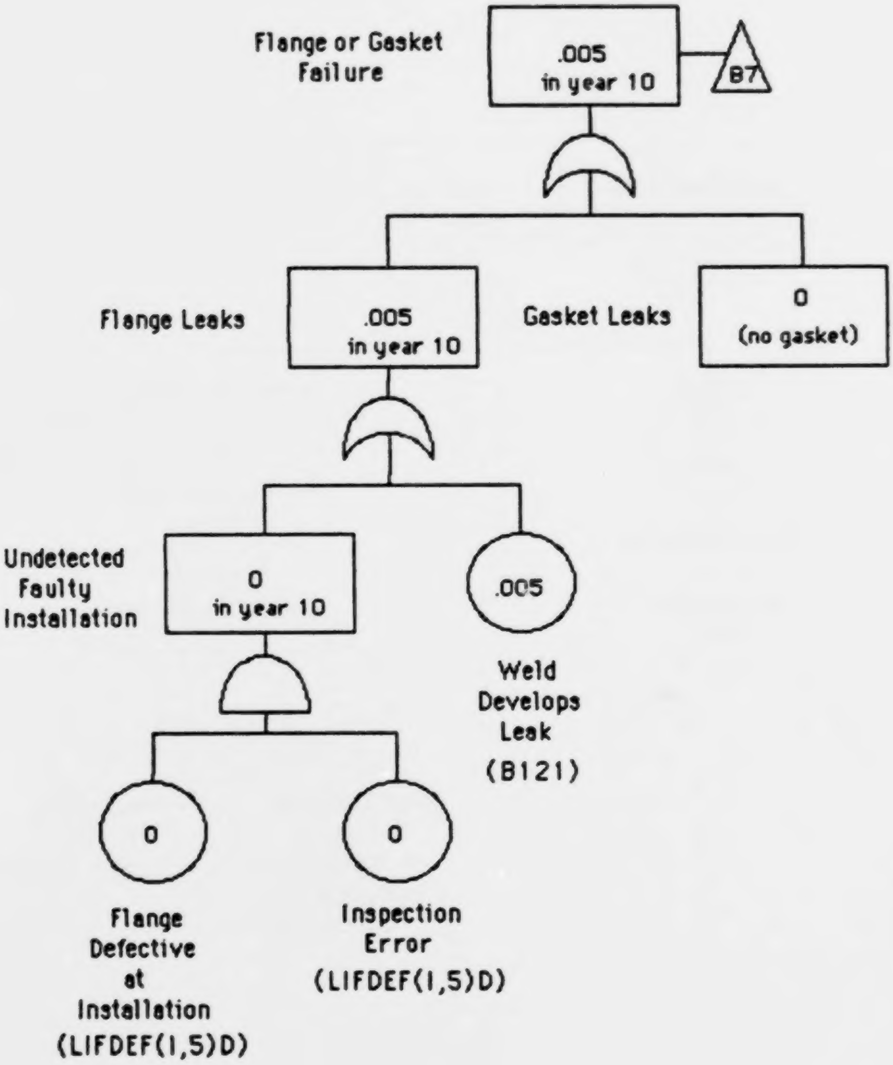

Flange or Gasket Failure
.005 in year 10
B7
Flange Leaks
.005 in year 10
Gasket Leaks
0 (no gasket)
Undetected Faulty Installation
0 in year 10
.005
Weld Develops Leak (B121)
0
0
Flange Defective at Installation (LIFDEF(1,5)D)
Inspection Error (LIFDEF(1,5)D)

FIGURE 22. EXTERNAL CATASTROPHES FOR A 5000-GALLON UNDERGROUND STORAGE TANK

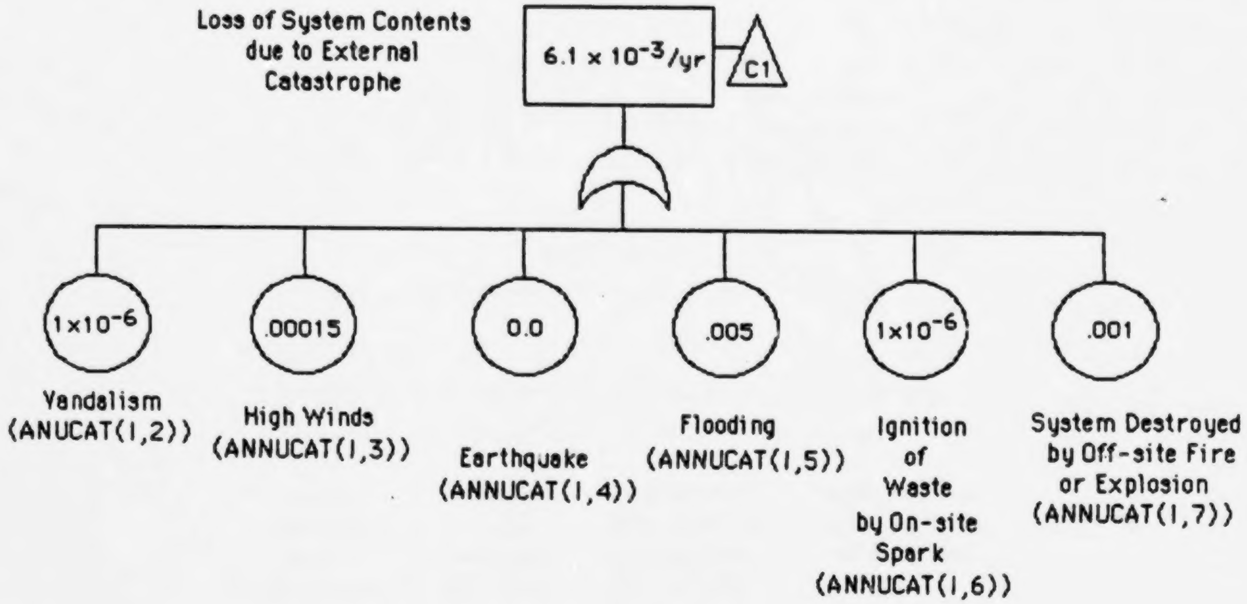
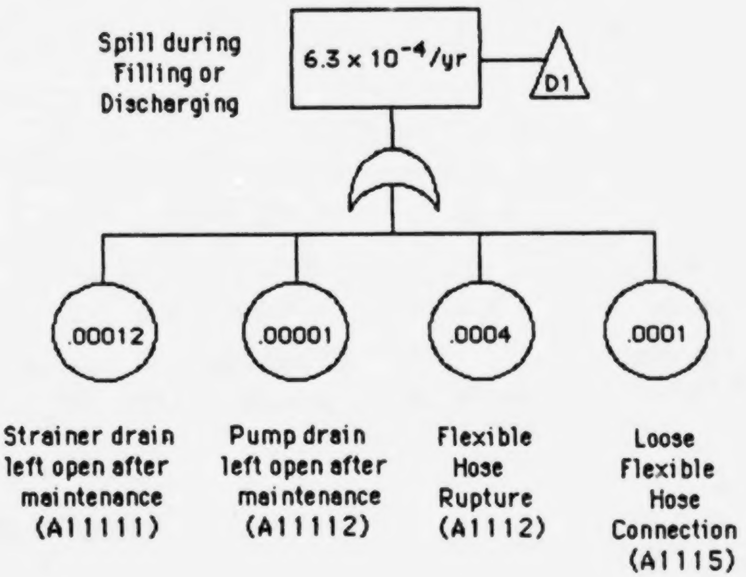

Loss of System Contents due to External Catastrophe
6.1 x 10⁻³/yr
C1
1x10⁻⁶
Vandalism (ANUCAT(1,2))
.00015
High Winds (ANNUCAT(1,3))
0.0
Earthquake (ANNUCAT(1,4))
.005
Flooding (ANNUCAT(1,5))
1x10⁻⁶
Ignition of Waste by On-site Spark (ANNUCAT(1,6))
.001
System Destroyed by Off-site Fire or Explosion (ANNUCAT(1,7))

FIGURE 23. ACCIDENTAL SPILLS FOR A 5000-GALLON UNDERGROUND STORAGE TANK


Spill during Filling or Discharging
6.3 x 10^-4/yr
D1
.00012
.00001
.0004
.0001
Strainer drain left open after maintenance (A11111)
Pump drain left open after maintenance (A11112)
Flexible Hose Rupture (A1112)
Loose Flexible Hose Connection (A1115)

- The soil around the pipes has a resistivity of 2000 ohm-cm and a pH of 5.
- The waste is flammable.
- The facility is located on a flood plain in a tornado region.

Based on these characteristics, we have computed the year-10 probabilities for each basic event and combined these probabilities to show the probabilities for intermediate and top events. In order to do this, we have replaced all time-to-failure distributions with these year-10 failure probabilities and have converted all monthly probabilities into annual probabilities.

To calculate the probabilities for the upper events on these fault trees, we had to take account of the presence of .AND. and .OR. gates. For events that are connected by .AND. gates, we calculated the upper-event probabilities by multiplying the initiating-event probabilities.

In the case of .OR. gates, the computation was more complex, requiring first the calculation of the probability that none of the events occurs, and then the subtraction of that probability from 1 in order to obtain the probability that one or more of the events occurred in some combination. Thus, for two events with probabilities p_1 and p_2, this probability is given by $[1-(1-p_1)x(1-p_2)]$. If p_1 and p_2, are small, this value can be approximated by $p_1 + p_2$. This simplification is generally sufficient whenever the algebraic sum is less than 0.1.

Figures 19-23 present a useful graphic depiction of the way that the probabilities and the fault trees relate. It must be realized, however, that such figures necessarily simplify the Monte Carlo model's approach to fault tree evaluation. These figures, for example, cannot allow for multiple occurrences of those events which the Monte Carlo model samples on a monthly basis. In addition, unlike the Monte Carlo model, such figures cannot account for the effects of prior failures on the year-10 failure probabilities, for these effects will vary from iteration to iteration. Instead, these figures are based simply on the failure distributions listed in Table 13, with no consideration of the possibility that a component might fail and be replaced prior to year 10.

With these caveats, however, Figures 19 through 23 still provide useful insights into the Hazardous Waste Tank Failure Model. They show, for example, that for underground storage tanks, leaks and ruptures are by far the most likely failure mechanisms. This does not mean, though, that all of the other failure mechanisms are unimportant; external catastrophes, for example, may be relatively unlikely, but when they occur, they produce large releases. Some release mechanisms, however, are comparatively unimportant. Accidental spills, for example are not only the least likely release mechanism, but they are also unlikely to involve large volumes (see Section 4.10 below). Similarly, overfills are unimportant loss mechanisms for underground storage tanks, for such tanks are infrequently filled to near capacity, and only have overflow routes if they are already leaking for other reasons. Thus, even though Figure 20B indicates that manual emergency shut-off systems have a 13% failure rate, these systems appear to be satisfactory for underground storage tanks.

Above-ground tanks, however, are much more likely to overflow, for their vents provide ready overflow routes. In addition, treatment tanks are also much more vulnerable to overflow, for not only are they generally aboveground, but they are also repeatedly filled nearly to capacity. Figure 24 therefore depicts the overflow fault tree for a batch treatment tank with manual controls. We assume that this tank operates 8 hours per day and processes 4 batches per day. Figure 25 depicts the overflow probabilities for a similar tank using a continuous process and automatic controls. These fault trees indicate that overflows are very probable for treatment tanks with manual shut-off systems, but less frequent for systems with automatic shut-off.

Probability calculations such as those illustrated in Figures 19 through 25 were very important to the development of our Monte Carlo model. Such calculations gave us benchmark failure rates against which to compare the results of the computer simulation. In addition they allowed us to determine visually which stochastic events deserved the most study.

These sensitivity analyses indicated that three failure mechanisms are particularly important: overflows, ruptures, and corrosion holes. We have

FIGURE 24A. OVERFLOWS FOR A 5000-GALLON TREATMENT TANK WITH 4 BATCHES PER DAY AND MANUAL SHUT-OFF

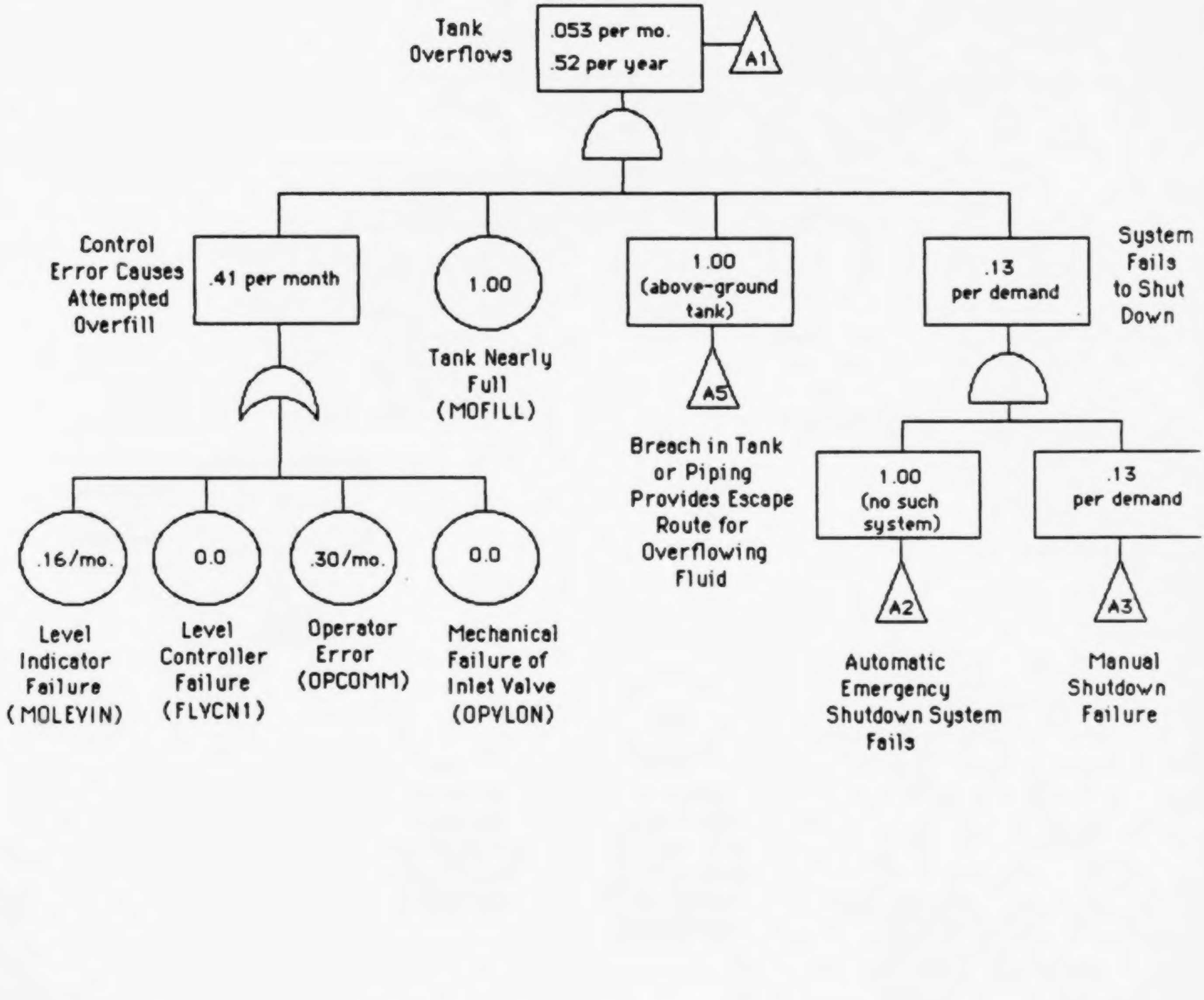

Tank Overflows
.053 per mo.
.52 per year
A1
Control Error Causes Attempted Overfill
.41 per month
1.00
Tank Nearly Full (MOFILL)
1.00 (above-ground tank)
A5
Breach in Tank or Piping Provides Escape Route for Overflowing Fluid
.13 per demand
System Fails to Shut Down
.16/mo.
Level Indicator Failure (MOLEVIN)
0.0
Level Controller Failure (FLYCN1)
.30/mo.
Operator Error (OPCOMM)
0.0
Mechanical Failure of Inlet Valve (OPVLON)
1.00 (no such system)
A2
Automatic Emergency Shutdown System Fails
.13 per demand
A3
Manual Shutdown Failure

FIGURE 24B. OVERFLOWS FOR A 5000-GALLON TREATMENT TANK WITH 4 BATCHES PER DAY AND MANUAL SHUT-OFF

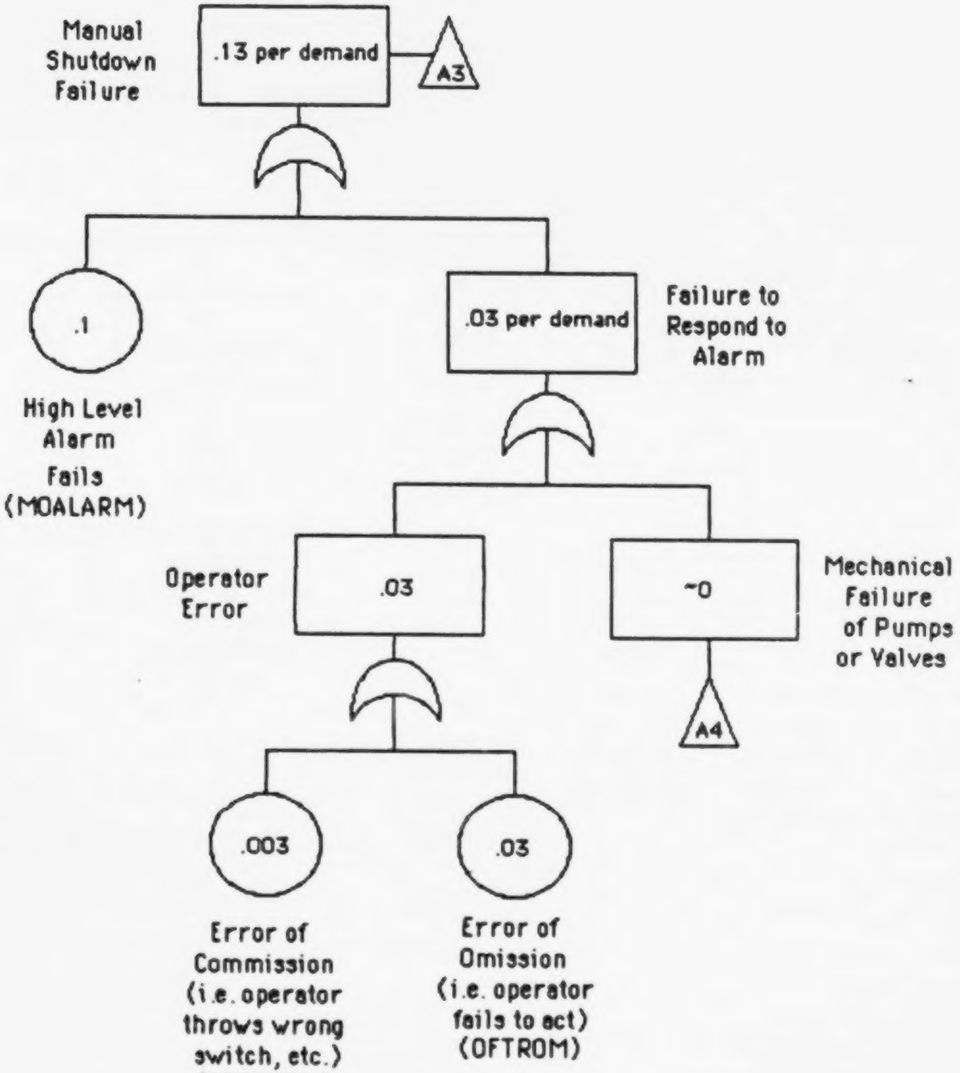

Manual Shutdown Failure
.13 per demand
A3
.1
High Level Alarm Fails (MOALARM)
.03 per demand
Failure to Respond to Alarm
Operator Error
.03
~0
Mechanical Failure of Pumps or Valves
A4
.003
.03
Error of Commission (i.e. operator throws wrong switch, etc.) (OFTRCOM)
Error of Omission (i.e. operator fails to act) (OFTROM)

FIGURE 24C. OVERFLOWS FOR A 5000-GALLON TREATMENT TANK WITH 4 BATCHES PER DAY AND MANUAL SHUT-OFF

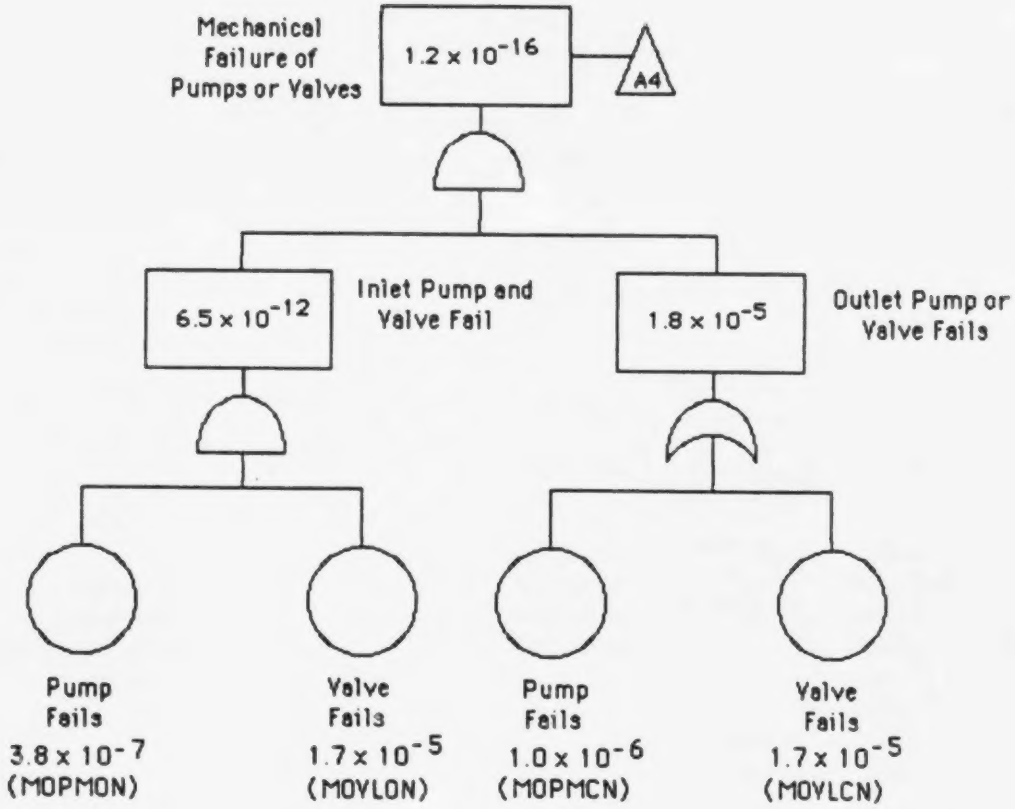

Mechanical Failure of Pumps or Valves
1.2×10^{-16}
A4
6.5×10^{-12}
Inlet Pump and Valve Fail
1.8×10^{-5}
Outlet Pump or Valve Fails
Pump Fails
3.8×10^{-7}
(MOPMON)
Valve Fails
1.7×10^{-5}
(MOVLON)
Pump Fails
1.0×10^{-6}
(MOPMCN)
Valve Fails
1.7×10^{-5}
(MOVLCN)

FIGURE 25A. OVERFLOWS FOR A 5000-GALLON TREATMENT TANK CONTINUOUS OPERATION WITH AUTOMATIC SHUT-OFF

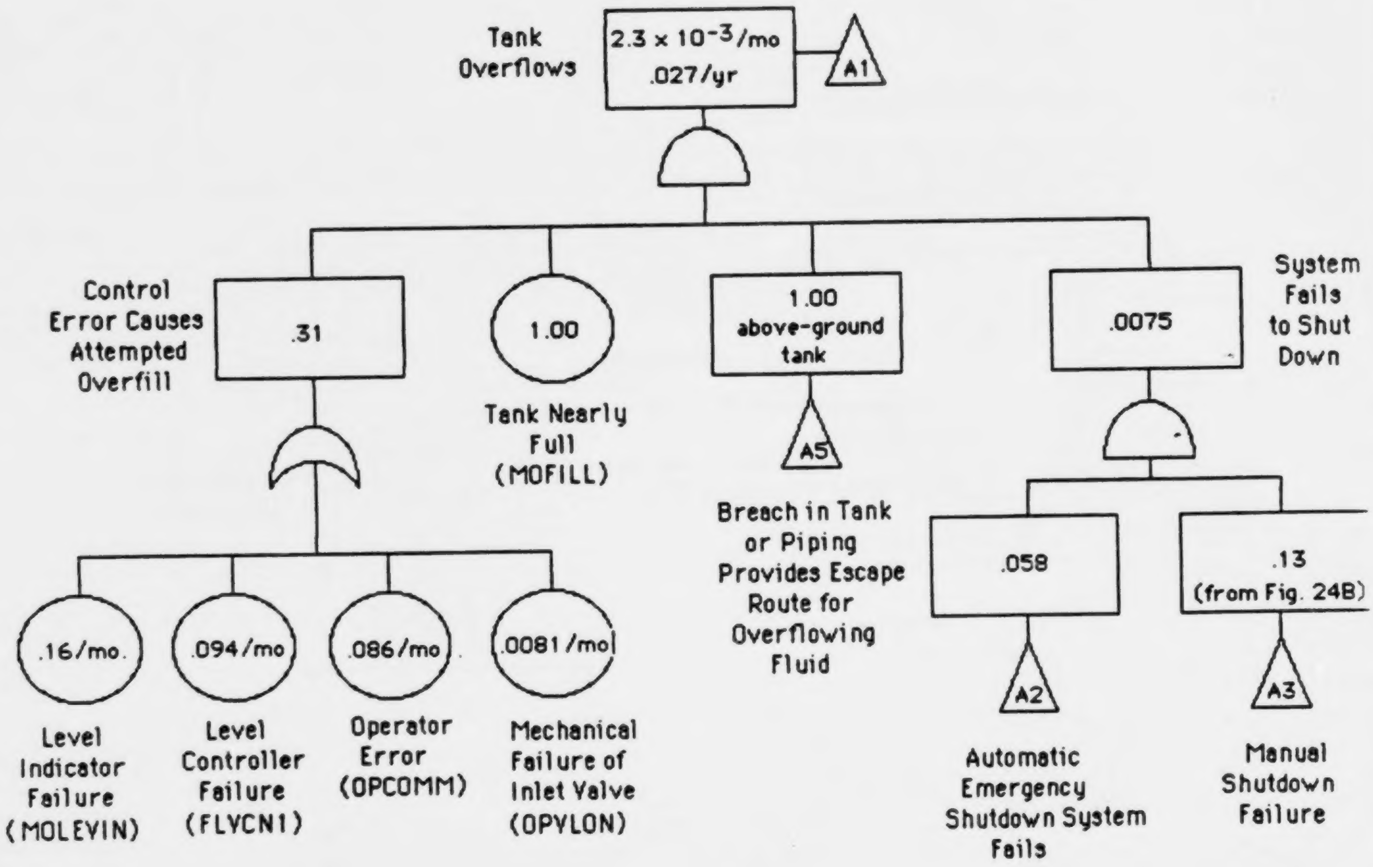
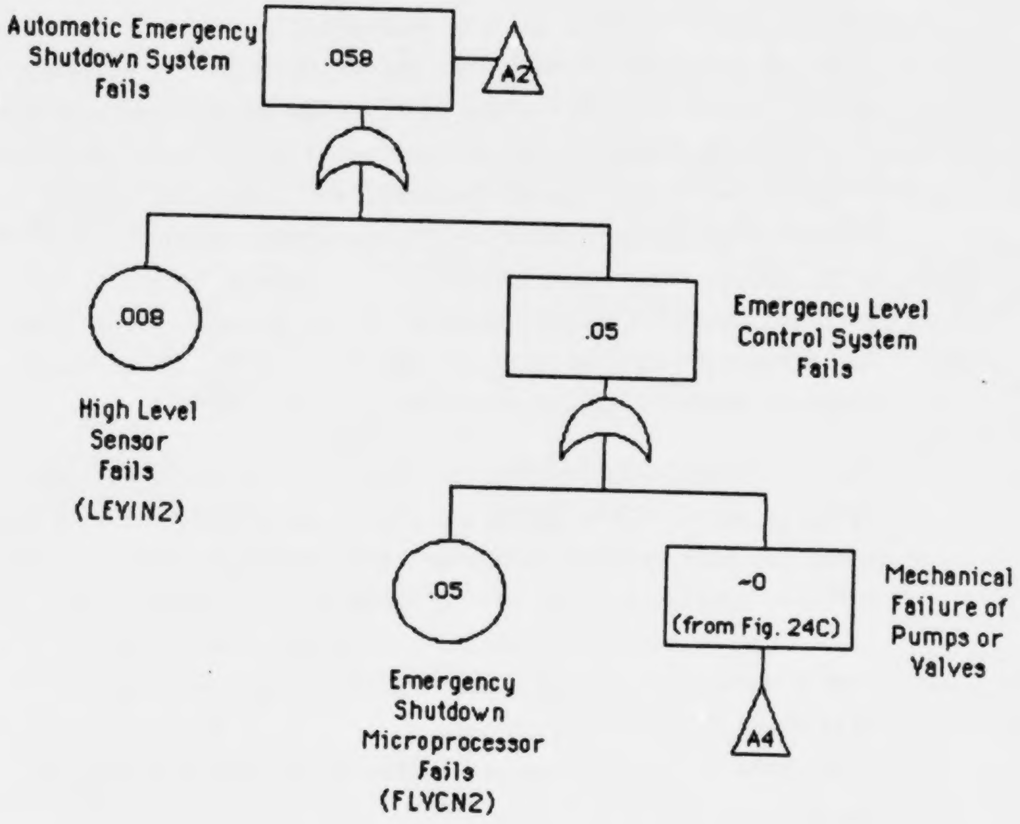

Tank Overflows
2.3 x 10-3/mo
.027/yr
A1
Control Error Causes Attempted Overfill
.31
1.00
Tank Nearly Full (MOFILL)
1.00 above-ground tank
A5
Breach in Tank or Piping Provides Escape Route for Overflowing Fluid
.0075
System Fails to Shut Down
.16/mo.
Level Indicator Failure (MOLEVIN)
.094/mo
Level Controller Failure (FLVCN1)
.086/mo
Operator Error (OPCOMM)
.0081/mo
Mechanical Failure of Inlet Valve (OPVLON)
.058
A2
Automatic Emergency Shutdown System Fails
.13 (from Fig. 24B)
A3
Manual Shutdown Failure

FIGURE 25B. OVERFLOWS FOR A 5000-GALLON TREATMENT TANK CONTINUOUS OPERATION WITH AUTOMATIC SHUT-OFF


Automatic Emergency Shutdown System Fails
.058
A2
.008
High Level Sensor Fails
(LEVIN2)
.05
Emergency Level Control System Fails
.05
Emergency Shutdown Microprocessor Fails
(FLVCN2)
~0
(from Fig. 24C)
Mechanical Failure of Pumps or Valves
A4

already described overflows in this section and in Chapter 3; we will describe corrosion in Sections 4.5 through 4.9. We will discuss ruptures in the remaining portions of this section.

Rupture probabilities are listed in Table 13 for tanks and pipes. Welded flange leaks are also a form of rupture. In deriving our rupture probabilities we have assumed that ruptures may result from a large variety of causes, such as settling, freeze/thaw action, vehicle collision, or faulty construction materials. Some of these factors, such as the cumulative effects of freeze/thaw action, become increasingly important as equipment ages; others, such as settling, become increasingly unlikely. We assume, therefore, that these conflicting aging effects cancel out, and that rupture probabilities are dominated by external events that are uncorrelated to the age of the component. For this reason, we have treated installation damage separately from ordinary ruptures, even though the physical damage from the two types of failures is likely to be similar. By modeling these two events separately, we in essence use installation damage to increase the probability of rupture in year 1 while still assuming that ordinary ruptures are equally likely in any year.

Table 13 lists separate rupture probabilities for pipes and tanks constructed of steel, stainless steel, and fiberglass. As that table shows, we have assumed that steel and stainless steel are equally likely to rupture; stainless steel may be resistant to corrosion, but it is not significantly stronger than ordinary carbon steel. Based on discussions with contractors, however, we have concluded that fiberglass is approximately twice as likely to rupture as is steel. We have therefore applied this ratio to our rupture and installation damage probabilities for both tanks and pipes.

Rupture mechanisms are different for above- and below-ground systems. Above-ground ruptures are most likely to occur due to vehicle collisions, collisions with fork lifts, freeze/thaw attack, or latent flaws in design, fabrication, or installation. Below-ground ruptures are most likely to result from settling, latent defects, or the driving of heavy equipment across the site. These rupture mechanisms are different, but we have assumed that their combined probabilities are approximately equal for above- and below-ground systems.

In addition, we have assumed that rupture probabilities are independent of tank capacity and pipe length. We make this assumption because components are designed to accommodate the normal range of operating stresses. Thus, design strengths should increase with tank capacity and pipe strength. We assume that the increased design strength for larger components cancels out the increased stresses to which they are subject, so that rupture probabilities are independent of system design.

Table 13 also lists rupture probabilities for double-walled tanks and pipes and concrete tanks. For double-walled components, we model the inner and the outer walls separately, but we assume that there is a 50% probability that a breach of the outer wall will also breach the inner wall. Because the inner wall is subject to fewer stresses than is the outer wall, we assume that a rupture is less likely to begin with the inner wall than with the outer wall. In addition, because operating pressures in hazardous waste tanks are generally low, we assume that only an insignificant fraction of ruptures initiating with the inner wall also breach the outer wall.

Concrete tanks are also subject to rupture, though in this case, these failures are more commonly referred to as cracks. Because the cracking of concrete is an age-dependent process, Table 13 lists a time-to-failure distribution rather than a binomial probability. This time-to-failure distribution is N(35,10). We chose it based on telephone conversations with concrete contractors and state highway officials. Our subsequent research has indicated that this time-to-failure distribution should vary with the design life of the tank. Thus, our failure distribution is probably an adequate approximation for the 20-year design life assumed by our original sources, but probably results in too many failures for 30- or 40-year design lives.

4.5 Tank Corrosion Model

Our Monte Carlo model can simulate above-, below-, and in-ground tank systems constructed of carbon steel, stainless steel, fiber-glass reinforced plastic (FRP), or concrete. We can also model a variety of corrosion protection systems, including:

- interior coatings;
- exterior coatings;
- cathodic protection; and
- interior and/or exterior corrosion with cathodic protection.

For ease of reference, the effects of these options are summarized for four different corrosion mechanisms in Tables 14 through 17. The following subsections will discuss these mechanisms in detail.

Underground Tanks

Steel tanks. For underground steel tanks, we have distinguished four basic corrosion mechanisms: localized exterior corrosion, generalized exterior corrosion, localized interior corrosion, and generalized interior corrosion.

Localized exterior corrosion is the most important of these processes. Like the other forms of corrosion, it is an electrochemical reaction involving a flow of current between the tank and the surrounding environment. When localized corrosion occurs, however, one or more irregularities in the tank surface or the surrounding soil channel the normal flow of current through a small area, accelerating the rate of corrosion. These irregularities are called point anodes, and they may result from local variations in soil pH, scratches in the tank wall, or stones or cinders in contact with the tank. In theory, a properly installed tank should have no point anodes. In practice, 70% to 85% of tanks do experience localized corrosion. Our localized exterior corrosion model is based on exterior corrosion data collected by the Petroleum Association for conservation of the Canadian Environment (PACE).

The PACE data consists of a survey of 108 leaking and 192 non-leaking underground service station tanks, giving the age of each tank and the aggressiveness of the soil in which it is buried. This survey data can be

TABLE 14. EFFECT OF TANK DESIGN ON LOCALIZED EXTERIOR CORROSION

Tank Design	Effect on Localized Exterior Corrosion Rate
BELOW-GROUND	
Carbon Steel	PACE Baseline corrosion rate, increased by $(A/440)^{.16}$ to account for tank surface area variations.
Stainless steel	Corrosion rate is 25% of the rate applicable to below-ground carbon steel tanks.
Fiberglass reinforced plastic (FRP)	Does not corrode. Probabilities of rupture and installation damage are double those used for steel.
Concrete	Generalized break-up (modeled as a rupture) after N(35,10) years. Seeps continuously.
Exterior coating	Delays onset of localized exterior corrosion by N(7,3) years (for all tank sizes). Localized corrosion begins with certainty following coating failure.
Cathodic protection	Delays onset of corrosion by $m \cdot N(10,5)$ years, where m = FNU (1,3) is a stochastically determins the level of cathodic protection maintenance. Once cathodic protection fails, corrosion follows PACE baseline.
Exterior coating with cathodic protection	Delays onset of corrosion until both cathodic protection and coating fail. Localized corrosion begins with certainty following corrosion-protection failure.
Stray currents	There is a 10% chance of stray currents at the site. If they exist, they will increase corrosion rate by a factor of x = B(1,2,4)

TABLE 14. EFFECT OF TANK DESIGN ON LOCALIZED EXTERIOR CORROSION (Continued)

Tank Design	Effect on Localized Exterior Corrosion Rate
ABOVE-GROUND (on cradles)	
Carbon steel	Corrode like low-SAV underground tanks of 5% as large a surface area.
Stainless steel	Corrodes at 25% of the rate applicable to above-ground carbon steel tanks.
Fiberglass reinforced plastic (FRP)	Does not corrode. Probabilities of rupture and installation damage are double those used for steel.
Concrete	Generalized break-up (modeled as a rupture) after N(35,10) years. Seeps continuously.
Exterior coating	Delays onset of corrosion by N(9,3) years (for all tank sizes). Localized corrosion begins with certainty following coating failure.
Cathodic protection	Does not affect above-ground tanks.
Stray currents	Do not affect above-ground tanks.
ABOVE-GROUND (on-grade)	Above-grade section corrodes like an above-ground tank of similar surface area; on-grade section corrodes like a below-ground tank of similar surface area. We only model the below-ground section, however, because it corrodes more quickly.
IN-GROUND	Above-grade section corrodes like above-ground tanks of similar surface area; below-grade section corrodes like below-ground tanks of similar surface area. The above- and below-grade portions are modeled independently.

TABLE 15. EFFECT OF TANK DESIGN ON GENERALIZED EXTERIOR CORROSION

Tank Design	Effect on Generalized Exterior Corrosion Rate
BELOW-GROUND	
Carbon steel	Corrosion rate in mils/yr is given by: $\max \left[1.4, \frac{SAV}{10} FNU\,(1.4,5)\right]$
Stainless steel	Corrosion rate is 25% of the rate applicable to below-ground carbon steel tanks.
Fiberglass reinforced plastic (FRP)	Does not corrode.
Concrete	Generalized break-up (modeled as a rupture) after N(35,10) years. Seeps continuously.
Exterior coating	Delays onset of generalized exterior corrosion by N(7,3) years. After coating fails, generalized exterior corrosion is same as for a new, uncoated tank.
Cathodic protection	Delays onset of generalized exterior corrosion until cathodic protection system fails. (See Table 14). Once the cathodic production system fails, the tank corrodes like a new, unprotected tank.
Exterior coating with cathodic protection	Delays onset of generalized exterior corrosion until both cathodic protection and the coating fail. After corrosion protection fails, generalized exterior corrosion is the same as for a new, unprotected tank.
Stray currents	Increase generalized exterior corrosion rate by same factor as applies to localized exterior corrosion.

TABLE 15. EFFECT OF TANK DESIGN ON GENERALIZED EXTERIOR CORROSION (Continued)

Tank Design	Effect on Generalized Exterior Corrosion Rate
ABOVE-GROUND (on cradles)	
Carbon steel	Corrodes at 1.4 mils/yr.
Stainless steel	Corrodes at .35 mils/yr
Fiberglass reinforced plastic (FRP)	Does not corrode.
Concrete	Generalized break-up (modeled as a rupture) after N(35,10) years. Seeps continuously.
Exterior coating	Delays onset of corrosion by N(9,3) years (for all tank sizes). Following coating failure, generalized exterior corrosion is the same as for a new, uncoated, above-ground tank.
Cathodic protection	Delays onset of corrosion until cathodic protection system fails (see Table 14). Once the cathodic protection system fails, the tank corrodes like a new, unprotected tank.
Exterior coating with cathodic protection	Delays onset of corrosion until both cathodic protection and coating fail. After corrosion-protection fails, generalized exterior corrosion is the same as for a new, unprotected tank.
Stray currents	No effect on above-ground tanks.
ABOVE-GROUND (on-grade)	Above-grade section corrodes like an above-ground tank of similar surface area; on-grade section corrodes like a below-ground tank of similar surface area. We only model the below-ground section, however, because it corrodes more quickly.
IN-GROUND	Above-ground section corrodes like above-ground tank; below-ground section corrodes like below-ground tank. We only model the below-ground section, however, because it corrodes more quickly.

TABLE 16. EFFECT OF TANK DESIGN ON LOCALIZED INTERIOR CORROSION

Tank Design	Effect on Localized Interior Corrosion Rate
BELOW-, ABOVE-, and IN-GROUND	
Carbon steel	Corrodes beneath fill pipe with a conditional normal distribution of .15N(8,5) years. Tank surface area has no effect.
Stainless steel	Corrodes at 25% of the rate applicable to carbon steel tanks.
Fiberglass reinforced plastic (FRP)	Does not corrode.
Concrete	Generalized break-up (modeled as a rupture) after N(35,10) years. Seeps continuously.
Interior coating	Delays onset of corrosion by N(7,3) years. After the coating fails, interior corrosion occurs at the rate applicable to a new, uncoated tank.
Cathodic protection	Delays onset of corrosion until cathodic protection system fails (see Table 14). Once the cathodic protection system fails, the tank corrodes like a new, unprotected tank.
Interior coating with cathodic protection	Delays onset of corrosion until both cathodic protection and coating fail. After corrosion-protection fails, tank corrodes like a new, unprotected tank.
Stray currents	Have no effect on interior corrosion.

TABLE 17. EFFECT OF TANK DESIGN ON GENERALIZED INTERIOR CORROSION

Tank Design	Effect on Generalized Interior Corrosion
BELOW-, ABOVE-, or IN-GROUND	
Carbon steel	Corrode according to the following empirical distribution:

Probability	Corrosion rate (mils/yr)
0.00 to .65	2
.65 to .90	FNU(2,10)
.90 to 1.00	FNU(10,20)

Tank Design	Effect on Generalized Interior Corrosion
Stainless steel	Corrodes at 25% of the rate applicable to carbon steel.
Fiberglass reinforced plastic (FRP)	Does not corrode.
Concrete	Generalized break-up (modeled as a rupture) after N(35,10) years. Seeps continuously.
Interior coating	Delays onset of corrosion by N(7,3) years. After coating fails, corrosion occurs at the rate applicable to a new, uncoated tank.
Cathodic protection	Delays onset of corrosion until cathodic protection system fails (see Table 14). Once the cathodic protection system fails, the tank corrodes like a new, unprotected tank.
Interior coating with cathodic protection	Delays onset of corrosion until both cathodic protection and coating fail. After corrosion-protection fails, tank corrodes like a new, unprotected tank.
Stray currents	Have no effect on interior corrosion.

converted into time-to-failure distributions for tanks in aggressive, moderate, and benign soils. The resulting distributions are presented in Table 18. In this table, soils are classified according to soil aggressiveness value (SAV), which is a numerical index developed by PACE to measure soil corrosivity. The calculation of SAV is detailed in Table 19. Further information about the PACE data, including the derivation of the time-to-failure distributions, is presented in Appendix A.

These time-to-failure distributions, however, are merely the starting points for the corrosion model. These distributions apply directly only to existing service station tanks, which at the time of the survey (1977) were usually constructed of quarter-inch bare steel. Since hazardous waste tanks may have other wall thicknesses, the PACE time-to-failure distributions must therefore be generalized. We accomplish this by sampling a time-to-failure from the PACE distribution and then dividing it into .25 inches to obtain a stochastically-determined corrosion rate, which we can then apply to tanks of thickness other than .25 inches. We then tally annual corrosion allotments, and when remaining wall-thickness reaches zero, the model determines that a corrosion failure has occurred.

We account for the fact that some tanks do not experience point corrosion by assuming that those tanks which have not failed by the end of 30 years are free of point anodes. Thus, 30.1% of the tanks in benign soils have a localized corrosion rate of zero, as do 23.4% of those in moderate soils, and 16.7% of those in aggressive soils. (We obtained these percentages by subtracting the year-30 cumulative failure probabilities from 1.00.) This does not mean that exterior corrosion does not occur in these tanks; rather, it means that corrosion will occur by a slower mechanism. This mechanism is generalized exterior corrosion.

Generalized exterior corrosion is a gradual loss of material over the entire tank surface. We assume that generalized exterior corrosion occurs at least as quickly underground as it does in air, but that except in unusually aggressive soils, it alone is unlikely to cause a quarter-inch tank to fail in less than 50 years. (Source: "Rogers Finds Leaks by Using Statistics," Petroleum Marketer, Nov./Dec., 1982, pp. 17-19.) This means

TABLE 18. CUMULATIVE TIME-TO-FAILURE DISTRIBUTIONS FOR QUARTER-INCH UNDERGROUND STEEL TANKS

	Cumulative Probability of Failure (%)		
Tank Age	Benign Soil (SAV $\leq$ 6)	Moderate Soil (7 $\leq$ SAV $\leq$ 12)	Agressive Soil (SAV > 13)
4	0	0	0
9	0	11.1	26.7
14	6.3	29.1	49.9
19	24.0	54.3	76.5
24	48.3	67.3	79.9
30	69.9	76.6	83.3

Note: the model obtains intermediate values by interpolation.

Source: PACE and Appendix A and F.

Caveat: This data applies only to 5,000 and 10,000 gallon service station tanks. Furthermore, the PACE survey was not conducted under statistically controlled methodologies, so the results may be biased. See Appendix F for further caveats.

Table 19. COMPUTATION OF SAV

I. BASIC CHARACTERISTICS		POINTS
• Soil Resistivity	<300	12
	300 - 1,000	10
	1,000 - 2,000	8
	2,000 - 5,000	6
	5,000 - 10,000	3
	10,000 - 25,000	1
	>25,000	0
• Soil pH	<3	8
	3 - 5	6
	5 - 6.5	4
	6.5 - 7.5	2
	7.5 - 9	1
	>9	0
• Soil Moisture	Saturated	3
	Damp	2
	Dry	0
II. DIFFERENTIAL CHARACTERISTICS		
• Soil Resistivity (ratio of extremes)	>1:10	3
	>1: 5	2
	>1: 3	1
	<1: 3	0
• Soil pH (Difference in pH Value)	3	2
	1.5 - 3	1
	0 - 1.5	0
III. SULFIDES		
	Positive	4
	Negative	0

Source: Petroleum Association for Conservation of the Canadian Environment (1983).

that the generalized exterior corrosion rate lies somewhere between 1.4 mils per year (the generalized corrosion rate in an air environment according to Ailor, 1982) and 5.0 mils per year (the rate required for a quarter-inch tank to fail in 50 years). We assume that the corrosion rate is uniformly distributed between these two values. In addition we assume that this corrosion rate varies proportionally to SAV, but that even in the most benign soils, the generalized exterior corrosion rate cannot be less than 1.4 mils per year. Mathematically, all of these assumptions can be expressed in a single equation:

$$\text{corrosion rate (in mil/yr)} = \max[1.4, \frac{\text{SAV}}{10}\,\text{FNU}(1.4,5)]$$

where 10 is the average value of SAV for all 300 of the PACE tanks, and the notation max[ ] means the maximum of the two values in the brackets. Note that for the average tank (SAV = 10), this distribution collapses to FNU(1.4,5).

Because both generalized and localized exterior corrosion are electrochemical processes, they may be accelerated by stray DC currents from improperly grounded motors or nearby electric rail lines. Based on conversations with Warren Rogers of Warren Rogers Associates, we have concluded that there is approximately a 10% chance that such equipment will be close enough to interfere with any given tank system. In addition, we have concluded that stray currents approximately double the rates of both localized and generalized exterior corrosion. More specifically, we have assumed that stray currents increase the corrosion rate by a multiplicative factor of x, where x is a random number drawn from a beta distribution with a minimum of 1, a mode of 2, and a maximum of 4. The resulting distribution could be termed a "conditional beta," where the 10% binomial probability determines the existence of stray currents and the beta distribution determines their intensity. Since these results will apply to the entire tank facility, we use the same value of x for all of the system's underground components, including tanks, pipes, and ancillary equipment.

In addition to exterior corrosion, tanks are also vulnerable to interior corrosion. This corrosion may be localized or generalized, and may result from a variety of causes, including materials defects, poor seam construction, accumulated grit or sludge, or acids generated by anaerobic bacteria living near the bottom of the tank.

Data collected by the American Petroleum Institute (API) indicates that localized interior corrosion occurs in only 15% of service station tanks. If it occurs, localized internal corrosion is probably a more rapid process than localized external corrosion, so we have assigned it a conditional time-to-failure distribution of .15 N(8,5) (see Appendix A). We can obtain an average corrosion rate by sampling this distribution and dividing the time-to-failure into .25", as we did for localized exterior corrosion. We can then apply this corrosion rate to tanks of any thickness. Note that for the 85% of tanks which do not experience localized interior corrosion, the localized internal corrosion rate is zero.

Generalized interior corrosion, however, always occurs at a non-zero rate. According to the sources cited in Appendix A, this form of corrosion is likely to range from 2 to 20 mils per year. Because we believe that lower corrosion rates are the most likely, we have used this information to construct the following empirical distribution of generalized interior corrosion rates:

Cumulative Probability	Corrosion rate (mils/yr)
0 to .65	2
.65 to .90	FNU(2, 10)
.90 to 1.00	FNU(10, 20)

All four corrosion mechanisms may act simultaneously. If this is the case, we must combine their individual corrosion rates to determine the overall effect. In doing this however, it is not proper to simply add all four corrosion rates together; that would implicitly assume that localized interior and localized exterior pits occur at the same place -- a highly unlikely event. Furthermore, because the PACE and API data were obtained from empirical observations rather than theoretical computations, it is likely that our localized exterior and localized interior corrosion rates already include their respective generalized corrosion rates.

Thus, only certain combinations of corrosion mechanisms need to be considered. Generalized interior corrosion must be added to localized exterior corrosion (in most cases this will have little effect on the failure date, but in a few instances it will allow a localized exterior pit to corrode through more quickly if the interior wall is undergoing unusually rapid generalized corrosion), and generalized exterior corrosion must be added to localized interior corrosion (accounting for those occasions when an interior pit reaches a rapidly corroding exterior wall). If there is no localized corrosion, then generalized interior and exterior corrosion rates must be combined to determine the date at which generalized corrosion causes a failure in a large segment of the wall.

Coated underground tanks. Tanks may be coated in an attempt to impede corrosion by preventing corrosive materials from reaching the tank surface. Coatings may be applied to either the interior or the exterior of the tank, and as long as they are intact, they effectively prevent the onset of either localized or generalized corrosion.

Coatings, however, do not last indefinitely. Instead, the sources identified in Appendix A indicate that both interior and exterior coatings fail with a time-to-failure of N(7,3) years. When failure occurs, the coating must be replaced, or corrosion will begin. Replacement of an interior coating is relatively easy, but replacing an exterior coating requires that the tank first be exhumed. Furthermore, the detection of an exterior coating failure requires careful inspection -- also requiring that the tank be exhumed. For these reasons, we have assumed that failed exterior coatings will not be repaired. Since the tank will therefore begin corroding from the outside at about the same time as the interior coating fails, we assume that the owner will not bother to repair a failed interior coating without also repairing the exterior coating. It is therefore relatively unlikely that either interior or exterior coatings will be repaired, and we have not included any form of coating repair or replacement in our underground tank model.

Once an exterior coating fails, the onset of localized corrosion becomes a certainty, for gaps in the coating provide a ready supply of point anodes.

(Source: National Association of Corrosion Engineers, personal communication.) Thus, the time-to-failure distributions presented in Table 18 must be rescaled so that for all three soil types the cumulative probability of failure eventually reaches 100%. The rescaled time-to-failure distributions are presented in Table 20. For interior coatings, however, the effect of coating gaps is less certain; for want of better data, we assume that following a coating failure, the tank corrodes like a new, uncoated tank.

Because large tanks are more likely to have unusually deep localized exterior corrosion holes, tank size will influence the localized exterior corrosion rate once an exterior coating fails. This will not be the case for interior coatings, however, because localized interior corrosion will generally be confined to the region beneath the fill tube. As before, we assume that the area of this region does not vary significantly with tank capacity.

For exterior coatings, we assume that the area correction factor is $A/A_0{}^{.16}$, where A is the surface area of the typical service station tank (approximately 440 square feet). The value of A to be used in this formula is the area of the entire tank surface, not merely the area of the coating failures. This is because the area correction factor is merely a scaling factor which we can use simply by assuming that the area of coating failure is proportional to the tank's surface area. We therefore never need to know the actual area or number of coating failures.

Cathodic protection. Cathodic protection is an entirely different form of corrosion protection. Rather than attempting to prevent corrosion by precluding contact with corrosive materials, it imposes a reverse electrical current on the protected components, inhibiting the electrochemical reactions that cause corrosion. Cathodic protection may be used on both the exterior and interior of the tank. Exterior cathodic-protection systems obtain the desired current flow by using a charged electrode in the surrounding soil; interior systems suspend an electrode in the waste. We assume that a cathodically protected tank uses both exterior and interior electrodes. We also assume that these electrodes are driven by the same

TABLE 20. COATED UNDERGROUND TANKS: TIME-TO-FAILURE DISTRIBUTION FOR QUARTER-INCH STEEL TANKS FOLLOWING THE FAILURE OF AN EXTERIOR COATING

Tank Age	Cumulative Probability of Failure (%)		
	Benign soil (SAV $\leq$ 6)	Moderate Soil (7 $\leq$ SAV $\leq$ 12)	Aggressive Soil (SAV $\geq$ 13)
4	0	0	0
9	0	14.5	32.0
14	9.0	38.0	59.9
19	34.3	70.9	91.8
24	69.1	87.9	95.9
30	100.0	100.0	100.0

Note: the model obtains intermediate values by interpolation.

power supply. If this power supply fails and is not repaired, cathodic protection will fail simultaneously for both tank surfaces. Since power supply failure is an important cause of cathodic-protection failure, we therefore assume that these two systems always fail in tandem.

Properly installed and maintained, cathodic protection systems should prevent corrosion indefinitely. They require regular monitoring, however, and prompt repair or replacement of failed components. According to the National Association of Corrosion Engineers, the leading cause of cathodic-protection failure is poor maintenance. Furthermore, once localized corrosion has started, repair of the cathodic-protection system will be ineffective, for it is difficult to get proper current density into the center of an existing pit. For these reasons, we have assigned cathodic-protection systems a time-to-failure distribution of $(m)\cdot N(10,5)$ where m is a random number between 1 and 3 indicating the quality of the maintenance effort. A value of 1 means that no maintenance is undertaken; a value of 3 indicates that the operator carefully follows the prescribed maintenance schedule. We multiply this number by the sampled time to failure in order to delay failure for well-maintained systems.

Once cathodic protection fails, the tank begins to corrode in the same manner as a new, unprotected tank. If the tank has both a coating and cathodic protection, it does not begin to corrode until both the coating and the cathodic-protection system have failed; it then corrodes like a coated tank whose coating has failed.

Construction materials. A third way to prevent corrosion is by constructructing tank shells from fiberglass, stainless steel, or concrete, because fiberglass and concrete do not corrode, and stainless steel corrodes at only 25% the rate applicable to carbon steel (Peters and Timmerhaus, 1980). The use of these materials is not without its drawbacks, however. Stainless steel is expensive, concrete seeps continuously and may develop cracks (See Section 4.4), and fiberglass is twice as vulnerable to rupture or installation damage as is carbon steel (see Section 4.4).

The seepage rate for a concrete tank is given by the following formula:

$$dQ/dt = A(1 + d/t)K \left[\frac{\mu_{H_2O}}{\mu_{waste}}\right]\left[\frac{\varphi_{waste}}{\varphi_{H_2O}}\right]$$

where:

dQ/dt = the rate of leakage

A = the surface area of the tank (sides and bottom only)

d = the average fluid depth in the tank

t = the thickness of the concrete

K = the permeability of the concrete to water (2.5×10^{-9} cm/sec)

μ_{H_2O} = the viscosity of water

μ_{waste} = the viscosity of the waste

φ_{waste} = the density of the waste

φ_{H_2O} = the density of water

Using this equation, we find that a rectangular 10,000-gallon concrete tank containing an aqueous waste with an average fluid depth of 6 feet will have a seepage rate of about 90 gallons per year. This seepage rate will continue throughout the tank's operating life.

In addition to continuous seepage, concrete tanks are also subject to a type of gradual disintegration that is often referred to as "corrosion." (U.S. Department of the Interior, Concrete Manual, 1981). The result of this process, however, is generalized cracking rather than isolated corrosion holes, so we have included it in the time-to-failure distribution for concrete tank ruptures (Section 4.4), rather than in this section.

Tank Size. In addition to the modifications necessary to account for corrosion protection and the use of alternative construction materials, the underground tank corrosion model must also be modified to account for variations in tank size. The PACE data were obtained from service station tanks, most of which probably had capacities of approximastely 5,000 gallons. Hazardous waste tanks, however, can range from 200 gallons to millions of gallons. The larger a tank is, the more likely it is to develop an unusually deep corrosion pit, and the sooner will be its first failure.

There are no good data describing the effect of tank size on time-to-failure. The best data source is a pipeline corrosion model developed by Rossum. This model indicates that the deepest pit in an area of A square feet is given by:

$$x = x_0 \left(\frac{A}{A_0}\right)^{.16}$$

where

x = the depth of the deepest pit in an area of A square feet, and

x_0= the depth of the deepest pit in an area of A_0 square feet.

We can easily incorporate this equation into the PACE model. A_0 is now the surface area of a 5000-gallon service station tank (about 440 square feet), A is the area of the hazardous waste tank under consideration, and x_0 is the localized exterior corrosion rate (which is linearly related to the depth of the deepest pit). Therefore, the localized exterior corrosion rate is related to the PACE baseline rate by a scaling factor of $(A/A_0)^{.16}$.

This area correction factor applies only to localized exterior corrosion, for that is the only type of tank corrosion which is affected by area. Generalized exterior corrosion and generalized interior corrosion are by definition area-independent, and the API data indicates that localized interior corrosion is confined to the region beneath the fill tube. The area of this region is not strongly affected by variations in the tank capacity.

Above-ground Tanks on Cradles. Like underground tanks, above-ground tanks are vulnerable to localized exterior, generalized exterior, localized interior, and generalized interior corrosion. Both types of interior corrosion will be the same for these tanks as for underground tanks, and generalized exterior corrosion will occur at the rate appropriate for an air environment (1.4 mil/yr).

Because the atmosphere does not contain point anodes, localized exterior corrosion will be unlikely on most of the tank's surface. The tank's seams and its points of contact with its support cradles, however, provide surface irregularities, and even in an air environment, these can serve as point anodes (National Association of Corrosion Engineers, telephone conversation). Thus these portions of the tank's surface are vulnerable to localized pitting (Perry and Chilton, 1973, p. 23-3). We assume that these vulner- able regions account for about 5% of the tank's surface. Because air environments are probably less corrosive than most soils, we have assumed that localized exterior corrosion at these locations is similar to localized exterior corrosion of a below-ground tank in a benign soil. To account for the limited locales at which such corrosion is likely, we use the $(A/440)^{.16}$ adjustment factor to reduce the effective surface area of the tank to 5% of its actual value.

If there is an exterior coating, exterior corrosion will not begin until the coating fails. This will occur after N(9,3) years (see Appendix A). Once the coating fails, exterior corrosion will occur with certainty at the points of failure. Generalized exterior corrosion will occur at 1.4 mils per year; localized exterior corrosion will occur at the rate applicable to exterior coating failures on low-SAV underground tanks with 5% as large a surface area.

Instead of using coatings, above-ground tank facilities may reduce corrosion failures by using corrosion-resistant construction materials. These materials are modeled like their below-ground counterparts. Thus, above-ground stainless steel tanks corrode only 25% as quickly as above-ground carbon steel tanks, while above-ground concrete tanks are subject to the same seepage losses and cracking problems as underground concrete tanks. Fiberglass tanks do not corrode, but they are twice as likely to rupture as their carbon steel counterparts.

In-ground Tanks and On-grade, Above-ground Tanks. In-ground tanks and on-grade, above-ground tanks can be modeled by combining our above-ground and below-ground corrosion models. We assume that the below- or on-grade portions of such tanks corrode like below-ground tanks of similar surface area. Their above-ground portions corrode like above-ground tanks, but instead of experiencing localized corrosion at their seams and points of contact with cradles, these tanks corrode at their seams and near their points of contact with the ground. Because above-ground corrosion is generally a slower process than below-ground corrosion, however, we have only modeled the on-or below-grade sections of such tanks.

Multiple-Tank Systems. If a hazardous waste facility has more than one tank, we model each tank independently, re-sampling the probability distribution for all forms of corrosion and all forms of corrosion-protection failure. If there is a cathodic-protection system, we assume that it includes all of the tanks. In addition, we assume that the entire cathodic-protection system is connected to the same power supply. If this power supply fails and is not repaired, cathodic protection will fail for all of the tanks.

4.6 Pipe Corrosion

Like tanks, pipes are subject to four forms of corrosion: localized exterior corrosion, generalized exterior corrosion, localized interior corrosion, and generalized interior corrosion. Also like tanks, pipes may or may not be coated or cathodically protected, and may be constructed of carbon steel, stainless steel, or fiberglass. They may be above-ground or below-ground. We model these various pipe designs similarly to the equivalent tank designs, first determining the time to corrosion-protection failure, then using time-to-failure or corrosion-rate distributions to calculate corrosion rates for each of the corrosion mechanisms. We then combine these corrosion rates to calculate the total effect of all of these mechanisms on pipes of varying thicknesses.

Our pipe-corrosion model, however, has some important differences from our tank-corrosion model. First, it assumes that the pipes from which our baseline corrosion data were obtained have a thickness of .19 inches rather than the .25 inches applicable to tanks. In addition, in order to take full advantage of available data, our pipe model uses a combination of the PACE tank-corrosion data and a pipe-corrosion formula developed by Rossum

(1968). Thus, our pipe-corrosion model involves somewhat different time-to-failure distributions than does our tank corrosion model.

For convenience of reference, Tables 21 through 24 summarize the effects of pipe system design on corrosion rates for localized exterior, generalized exterior, localized interior, and generalized interior corrosion, respectively. We will describe these effects in more detail in the remainder of this section; complete derivations of the time-to-failure distributions may be found in Appendix A.

Localized exterior corrosion. The Rossum pipe corrosion model is directly applicable to pitting corrosion (i.e., localized exterior corrosion) of underground, uncoated, carbon steel pipes. According to this model, the expected number of leaks at time t is given by:

$$L = A\left[\frac{1.06\ K}{z}\right]^{6.25}\left[\frac{t(10 - pH)}{\varphi}\right]^{6.25n}$$

where

L = the number of leaks at time t

A = the surface area of the pipe (square feet)

K = 170 for soils of good aeration
= 196 for soils of moderate aeration*
= 222 for soils of fair aeration
= 355 for soils of poor aeration

z = the thickness of the pipe in mils

t = the age of the pipe (in years)

pH = the soil pH (must be between 5 and 9)

φ = the soil resistivity

n = 1/6 for soils of good aeration
= .236 for soils of moderate aeration**
= 1/3 for soils of fair aeration
= 1/2 for soils of poor aeration

* We have obtained this value by averaging the values for good and fair aeration.

** We have obtained this value by taking the geometric mean of the values for good and fair aeration.

TABLE 21. EFFECT OF PIPE SYSTEM DESIGN ON LOCALIZED EXTERIOR CORROSION

Pipe System	Effect on Localized Exterior Corrosion Rate
BELOW-GROUND	
Carbon steel	Time-to-failure is predicted by a stochastic modification of a leak-prediction formula by Rossum (1968).
Stainless steel	Corrodes at 25% of the rate applicable to below-ground carbon steel pipes.
Fiberglass reinforced plastic (FRP)	Does not corrode. Probabilities of rupture and installation damage are double those applying to steel pipes.
Exterior coating	Delays onset of localized exterior corrosion by N(7,3) years. Localized corrosion begins with certainty following coating failure.
Cathodic protection	Delays onset of corrosion until cathodic protection system fails (see Table 14). Once cathodic protection fails, pipe corrodes like a new, unprotected pipe.
Exterior coating with cathodic protection	Delays onset of corrosion until both cathodic protection and coating fail. Localized corrosion begins with certainty following corrosion protection failure.
Stray currents	If stray currents are present, they will have the same effect on pipes as they do on underground tanks.

TABLE 21. EFFECT OF PIPE SYSTEM DESIGN ON LOCALIZED EXTERIOR CORROSION (Continued)

Pipe System	Effect on Localized Exterior Corrosion Rate
ABOVE-GROUND	
Carbon steel	Corrodes with conditional time-to-failure distribution given by: $T = .11\ (A/10)^{.16} N \left[16(10/A)^{.16},\ 6.6(10/A)^{.16}\right]$ where T is the time to failure.
Stainless steel	Corrodes at 25% of the rate applicable to above-ground carbon steel pipes.
Fiberglass reinforced plastic (FRP)	Does not corrode. Probabilities of rupture and installation damage are double those applicable to carbon steel.
Exterior coating	Delays onset of corrosion by N(9,3) years (for all pipe lengths). Localized corrosion begins with certainty following coating failure.
Cathodic protection	Has no effect above-ground.
Stray currents	Have no effect above-ground.

TABLE 22. EFFECT OF PIPE SYSTEM DESIGN ON GENERALIZED EXTERIOR CORROSION

Pipe Design	Effect on Generalized Exterior Corrosion Rate
BELOW-GROUND	
Carbon steel	Corrosion rate in mils/yr = $\max\left[1.4,\ \frac{SAV}{10}\ FNU(1.4,5)\right]$
Stainless steel	Corrosion rate is 25% of the rate applicable to below-ground carbon steel pipes.
Fiberglass reinforced plastic (FRP)	Does not corrode.
Exterior coating	Delays onset of generalized corrosion by N(7,3) years. After coating fails, generalized corrosion is the same as for new, uncoated pipes.
Cathodic protection	Delays onset of corrosion until cathodic protection system fails (see Table 14). Once cathodic protection fails, pipe corrodes like a new, unprotected pipe.
Exterior coating with cathodic protection	Delays onset of generalized exterior corrosion until both cathodic protection and the coating fail. After corrosion-protection fails, generalized exterior corrosion is the same as for a new, unprotected pipe.
Stray currents	Will increase the generalized exterior corrosion rate by the same factor as applies to tanks.

TABLE 22. EFFECT OF PIPE SYSTEM DESIGN ON GENERALIZED EXTERIOR CORROSION (Continued)

Pipe Design	Effect on Generalized Exterior Corrosion Rate
ABOVE-GROUND	
Carbon steel	Corrodes at 1.4 mils/yr.
Stainless steel	Corrodes at .35 mils/yr.
Fiberglass reinforced plastic (FRP)	Does not corrode.
Exterior coating	Delays onset of corrosion by N(9,3) years (for all pipe lengths). Following coating failure, generalized exterior corrosion is the same as for a new, uncoated, above-ground pipe.
Cathodic protection	Has no effect above-ground.
Stray currents	Have no effect above-ground.

TABLE 23. EFFECT OF PIPE SYSTEM DESIGN ON LOCALIZED INTERIOR CORROSION

Pipe System Design	Effect on Localized Interior Corrosion Rate
BELOW- or ABOVE-GROUND	
Carbon steel	The probability of localized interior corrosion is given by: $p = .024\ (A/10)^{.16}$ The corrosion rate for pipes which experience this form of corrosion is $(A/10)^{.16}$ times the corrosion rate obtained by sampling a time-to-failure distribution of N(8,5) for 190-mil pipes.
Stainless steel	Corrodes at 25% of the rate applicable to carbon steel pipes.
Fiberglass reinforced plastic (FRP)	Does not corrode.
Interior coating	Delays the onset of corrosion by N(9,3) years. After the coating fails, interior corrosion occurs at the rate applicable to a new, uncoated pipe.
Cathodic protection	Delays onset of corrosion until cathodic protection system fails (see Table 14). Once cathodic protection fails, pipe corrodes like a new, unprotected pipe.
Interior coating with cathodic protection	Delays onset of interior corrosion until both the cathodic-protection system and the coating fail. After corrosion-protection failure, localized interior corrosion is the same as for a new, unprotected pipe.
Stray currents	Have no effect on interior corrosion.

TABLE 24. EFFECT OF PIPE SYSTEM DESIGN ON GENERALIZED INTERIOR CORROSION

Pipe System Design	Effect on Generalized Interior Corrosion Rate
BELOW- or ABOVE-GROUND	
Carbon steel	Corrodes according to the following formula: corrosion rate = $(1-f)(1.4) + fr_T$ where f is the fraction of the time the pipe is in contact with the fluid (including a 30-minute drying time), and r_T is a corrosion rate sampled from the same generalized interior corrosion distribution as is used for tanks.
Stainless steel	Corrodes at 25% of the rate applicable to carbon steel.
Fiberglass reinforced plastic (FRP)	Does not corrode.
Interior coating	Delays onset of corrosion by N(9,3) years. After coating fails, corrosion occurs at the rate applicable to a new, uncoated tank.
Cathodic protection	Delays onset of corrosion until cathodic protection system fails (see Table 14). Once cathodic protection fails, pipe corrodes like a new, unprotected pipe.
Interior coating with cathodic protection	Delays onset of interior corrosion until both the cathodic-protection system and the coating fail. After corrosion-protection failure, generalized interior corrosion is the same as for a new, unprotected pipe.
Stray currents	Have no effect on interior corrosion.

This formula is very sensitive to soil resistivity and soil pH; doubling the resistivity, for example, will cut the expected number of leaks in half, while decreasing the pH from 7 to 6 will increase the expected number of leaks by 33%. In addition, since the chemical processes underlying corrosion vary with the amount of oxygen present, Rossum's formula is highly dependent on soil aeration. For 100 feet of 2-inch diameter, 190-mil pipe, in a soil with a resistivity of 5000 ohm-cm and a pH of 6, this equation gives the following values:

	Expected Number of Leaks		
Aeration	Year 10	Year 20	Year 40
good	.025	.51	1.04
moderate	.072	.20	.56
fair	.0084	.040	.16
poor	.001	.0092	.08

This model, however, merely predicts the expected number of holes. It does not give a stochastic distribution of times to failure. We have therefore converted it into a cumulative probability distribution by assuming that the nth hole develops at a random time between the dates when L = n - 1 and L = n + 1. We convert fractional values of L into probabilities to determine when during this interval the nth hole develops. Thus, at the date when L = 1, there is a 50% probability that the first leak has occurred, for L = 1 is half-way between L = 0 and L = 2. Similarly at L = 1.5, there is a 75% probablity that the first leak has occurred, for 1.5 is 75% of the way between 0 and 2. Furthermore, _if_ the first leak has occurred at L = 1.5, there is a 25% chance that a second leak has also developed. There is no chance, however, that a third leak will develop before L = 2.0.

This discussion reveals one important difference between the pipe-corrosion model and the tank-corrosion model: the pipe-corrosion model allows for multiple leaks, while the tank corrosion model only predicts the date at which the first leak occurs. If suitable data can be found, future versions of the tank-corrosion model will also allow for the development of multiple corrosion holes.

There is another important difference between the tank- and pipe-corrosion models. The tank-corrosion model is based on the soil's resistivity, pH, moisture content, and sulfide content, while the pipe-corrosion model uses the soil's resistivity, pH, and aeration instead. Thus the two models require different parameters, and changes in the non-overlapping parameters (moisture, sulfides, and aeration) can have significant effects on corrosion rates. The two models are not incompatible, however, because several of the parameters are strongly correlated. High moisture content, for example, is usually accompanied by relatively low resistivity and relatively poor aeration. In each of our simulation runs, therefore, we have taken care to specify a consistent set of soil characteristics.

Generalized exterior, localized interior, and generalized interior corrosion. Generalized exterior corrosion is very similar for pipes and tanks. We have therefore assigned the same probability distribution to both types of components. Because we assume that corrosion proceeds independently on separate pieces of equipment, however, we sample this distribution independently for each tank and each pipe. Thus, while tanks and pipes have the same probability distributions for generalized exterior corrosion, they need not have identical corrosion rates.

Generalized interior corrosion, however, does not have the same distribution for pipes and tanks. In pipes, fluid is seldom present, and generalized interior corrosion proceeds largely from atmospheric effects. We therefore use a corrosion rate of 1.4 mils per year (the rate appropriate for an air environment, Ailor, 1982), with a correction factor for the fraction of time that the pipe is in contact with the fluid. We obtain this correction factor in two steps. First, we compute the fraction of time when fluid is in contact with the pipe (including a 30-minute drying time following each pipe usage). We denote this fraction as f. Then we sample a generalized interior corrosion rate from the same distributions that we use for the generalized interior corrosion of tanks. We denote this corrosion rate as r_T. We then combine r_T and f in the following formula:

$$r \text{ (in mils/yr)} = (1-f)(.14) + fr_T$$

Where r is the generalized interior corrosion rate. Note that this expression degenerates to 1.4 mils per year if f = o (i.e. if fluid is never present).

Localized interior corrosion is a bit more difficult to model. In tanks, the API data show that this form of corrosion is 19% as likely as localized exterior corrosion, but tanks are always in contact with the fluid, while pipes are usually in contact with the air. On the other hand, localized interior corrosion appears to be strongly influenced by fluid motion. That is why tanks that fail due to localized interior corrosion generally do so at locations immediately below their fill tubes.

Fluid motion in tanks and in pipes only occurs during periods of fluid transfer. For a fill pipe, these periods correspond exactly to the periods of most significant fluid motion in the tank (because the tank experiences significant fluid motion only during filling). For a discharge pipe, differences in pumping rates may cause the fraction of the time during which fluid is in motion to differ from that applicable to the fill pipe. Since the same volume of fluid must pass through all three components, however, we assume that these variations are unimportant, and that like tanks, fill and discharge pipes are 19% as likely to undergo localized interior as localized exterior corrosion.

In order to use this percentage, however, we must first reconcile a difference between the Rossum underground pipe formula and the API service station data. According to the Rossum formula, all pipes undergo some degree of localized corrosion. Yet according to the API data, only 15% of service station pipes experience corrosion failure (see Appendix A for our derivation of this percentage). first consideration, these two predictions appear incompatible. The difference, however, is in the time period. The API data considered tank systems with an average age of 11 years; for many soil conditions, the Rossum formula often does not predict failure until considerably later. Thus, within the time horizon of the API data set, the Rossum formula does not predict 100% failure, and depending on assumptions about pipe length and soil characteristics, the two data sources can be readily reconciled. For example, according to our stochastic version of the Rossum formula, pipe segments with a surface area of 10 square feet in a moderate-aeration soil with a resistivity of 2000 ohm-cm and a pH of 5 show an 11% 20-year failure rate. Since this is well within the range indicated by the API data, we can use that data without introducing any serious inconsistencies into our model.

To derive an interior corrosion model, we therefore begin with the API data's indication that interior corrosion is 19% as common as exterior corrosion and that 15% of service station pipes fail due to corrosion. Since the 15% figure includes both interior and exterior corrosion failures, this means that 2.4% of service station pipes should experience interior corrosion failure.

This 2.4% figure, however, is valid only for pipes similar to those in service stations. We have assumed these pipes to have an area of 10 square feet (10 feet of 4" pipe or 20 feet of 2" pipe). Hazardous waste tank pipes may be much longer or much shorter. Consequently, we have used the surface-area adjustment factor that we had previously derived for tanks to also adjust for pipe-length variations. Thus, the probability of localized interior corrosion is $0.024\ (A/A_0)^{.16}$, where A_0 = 10 square feet.

In addition, we have assumed that like tanks, those pipes which develop localized interior corrosion have a baseline time-to-failure distribution of N(8,5). In order to account for the fact that longer pipes are more likely to develop unusually deep pits, we have adjusted the corrosion rate obtained from this distribution by $(A/10)^{.16}$.

Above-ground Pipes. Above-ground pipes also experience all four forms of corrosion. Three of these corrosion mechanisms, however, are easily described: generalized and localized interior corrosion are the same for above-ground pipes as they are for underground pipes, while generalized exterior corrosion is the same for above-ground pipes as it is for above-ground tanks (1.4 mils/yr). In order to model localized exterior corrosion, however, we have been forced to develop a new corrosion model, for the localized exterior model which we developed for underground pipes is inapplicable above-ground.

We have used a combination of the PACE tank data and the API service station data to develop this model. According to our underground pipe model, 15% of underground pipes fail due to corrosion. Since the probability of interior corrosion is 2.4%, we assume that the remaining 12.6% failure rate is due to localized exterior corrosion. Furthermore, the API data indicates that the time-to-failure distribution for pipes which do fail (due to either cause) is N(12,5) (see Appendix A). Although this distribution contains a mixture of internal and external corrosion failures, it will be dominated by localized exterior corrosion failures (because they are more common), and we can apply this distribution directly to this class of failures. Thus, according to the API data, the time-to-failure distribution for localized exterior corrosion of underground pipes is .126N(12,5).

Above-ground pipes, however, will not follow this distribution. Instead, based on reasoning parallel to that which we used for above-ground tanks, we assume that above-ground pipes will corrode like pipes in low-SAV soils, but only at the 5% of their surface areas accounted for by seams and points of support. We must therefore adjust the API time-to-failure distribution to account for surface area and SAV.

We adjust for surface area by applying an area adjustment factor of $(.05A/10)^{.16}$ to both the binomial probability of failure and the baseline corrosion rate obtained from sampling the conditional time-to-failure distribution. We correct for SAV by noting that according to the PACE data, 77% of medium-SAV and 70% of low-SAV tanks fail by localized exterior corrosion within 30 years. Assuming that the average pipe in the API study was buried in medium-SAV soil, and assuming that the effects of SAV on underground pipes and tanks are proportional, this means that 11% of low-SAV service station pipes should develop localized exterior corrosion (11% = 12.6% x (70% / 77%)). Furthermore, the PACE data (see Table 19, above) indicates that the average failure date for medium-SAV tanks experiencing point corrosion is 16 years. The average for low-SAV tanks is

21 years. Again assuming proportionality, this means that the time-to-failure distribution for low-SAV service station pipes should be N(16,6.6). Combining our SAV assumptions with our area adjustment factor, we obtain the following conditional normal distribution for above-ground pipes:

$$\text{time to failure} = .11(A/10)^{.16}\ N[16(10/A)^{.16},\ 6.6(10/A)^{.16}]$$

This adjustment factor applies to the time to failure, rather than the corrosion rate. Since time to failure and corrosion rate are inversely related, applying a factor of $(10/A)^{.16}$ to the time to failure is mathematically equivalent to applying a factor of $(A/10)^{.16}$ to the corrosion rate.

A note on area effects. As a comparison of our pipe- and tank-corrosion models would indicate, our use of area correction factors is different for pipes and tanks. For pipes, we have used an area correction factor for both the baseline probability and the baseline corrosion rate. For tanks, we only apply it to the corrosion rates.

We have modeled pipes and tanks differently because we believe that three factors control the onset of localized corrosion. One of these is the surface area of the buried metal. The others are the corrosivity of the soil and the care with which the component is installed. We have assumed that surface area is an important factor for localized corrosion events with low probabilities. In other words, we have assumed that the probability of pipe corrosion is relatively low because a pipe is small enough that it is relatively unlikely to experience a point anode. For tanks, however, the baseline probabilities of localized corrosion are on the order of 70-85%. We assume therefore, that the principal factors influencing the onset of tank corrosion are the corrosivity of the soil and the care with which the tank is installed. Surface area will be important, but its primary effect will be to determine the number of point anodes and thus the depth of the deepest pit.

We have generalized the preceding discussion to obtain the following rule of thumb: whenever the baseline probability of a corrosion event is less than 50%, we assume that component surface area will influence the probability of the onset of corrosion; whenever the baseline corrosion probability is over 50%, we assume that the component is already large enough that surface area has little influence on probability. Since all of our relevant baseline probabilities are either greater than 70% or less than 12%, we never had to elaborate this rule of thumb by developing a model to deal with intermediate cases. In addition, since our area adjustment factor requires an area more than 5000 times larger than baseline to increase a 12% probability to 50%, we did not need to modify that factor to assure that our area adjustments do not increase the failure probability by too much. For similar reasons, our model is insensitive to any choice of cutoff probabilities between 25% and 70%, so it is unnecessary for us to be precise in our determination of what value in that range is the theoretically best choice.

Corrosion protection. Pipes may be coated, cathodically protected, or constructed of fiberglass, concrete, or stainless steel. These corrosion protection techniques have the same effect on pipes as they have on tanks. Fiberglass pipes are corrosion-resistent; stainless steel pipes corrode one-fourth as rapidly as bare steel pipes; and cathodically protected pipes do not corrode until the cathodic-protection system fails. If there is cathodic protection for tanks, we assume that there is also cathodic protection for pipes. In addition, we assume that the pipes cathodic-protection system uses the same power supply as the tank's. If that power supply fails and is not repaired, cathodic protection will fail for both tanks and pipes.

Interior and exterior coatings also have the same effect on pipes as they do on tanks, delaying the time of failure by a time of N(7,3) years for exterior coatings on underground pipes, or N(9,3) years for coatings exposed primarily to an air environment (interior coatings or exterior coatings on above-ground pipes). Once the coating fails, interior corrosion and generalized exterior corrosion proceeds as for new, uncoated pipes, but localized exterior corrosion commences with certainty at the gaps in the coating. Since the Rossum model does not incorporate this effect even for underground pipes, we used the API and PACE data to determine the time-to-failure distributions following coating failure. As we discussed earlier, these distributions indicate that uncoated, medium-SAV pipes have a conditional time-to-failure distribution of N(12,5), while uncoated, low-SAV pipes have a conditional time-to-failure distribution of N(16,6). We have not previously calculated a conditional time-to-failure distribution for uncoated, high-SAV pipes, but calculations similar to those which we used for low-SAV pipes provide a conditional time-to-failure distribution of N(9,4).

We can apply these same time-to-failure distributions to coated pipes, for the effect of coating failures is to assure the onset of corrosion, not to alter its conditional time-to-failure distrubition. Therefore, following coating failure, we assume that coated pipes corrode with certainty according to the time-to-failure distribution appropriate for their locations. We account for variations in their lengths by multiplying the baseline corrosion rate by $(A/A_0)^{.16}$ where A_0 = 10 square feet, the typical surface area of a service station pipe.

Multiple-Pipe Systems. If a hazardous waste facility has more than one pipe, we model each pipe independently, re-sampling the probability distributions for all forms of corrosion and all forms of corrosion protection failure. If there is cathodic protection, however, we assume that the entire cathodic-protection system will fail simultaneously. Thus, we use the same date of failure for each pipe's cathodic-protection system. This date of failure is also the same as the date of failure for the tank's cathodic-protection system.

4.7 Pump and Valve Corrosion

Pumps and valves corrode similarly to short pipe segments. The effect of pump corrosion, however, depends on whether the pump is submersible or above-ground. Submersible pumps are located inside the tank, where even if they corrode they cannot release fluid to the exterior environment. Above-ground pumps, however, may be the source of releases. Corrosion of these pumps is very similar to above-ground pipe corrosion, with a few minor changes to higher interior corrosion rates to account for the pump's complex shape. The details of our pump-corrosion model are present in Appendix D.

It should be noted that pumps are unnecessary for underground waste storage tanks. These tanks are generally constructed so that they will be gravity-fed by drainage from a collection tank located at a higher elevation. They are discharged through a flexible hose connected to a portable pump on the pump-out truck. Thus, such systems do not contain on-site pumps, and we have generally not included pump corrosion in our underground storage tank simulations.

Valves are housed in short lengths of pipe that are physically distinct from the rest of the pipe. In theory, we could model these valve segments separately, but such an approach would needlessly complicate our model. Instead, we have treated each valve as a portion of the pipe to which it is attached, and have not distinguished between corrosion of the pipe and corrosion of the valve.

4.8 Erosion

In addition to corrosion, pipes and pumps are also subject to erosion. This process, which has effects very similar to generalized interior corrosion, results from mechanical abrasion by suspended solids in a flowing fluid. Wastes with low suspended solids will therefore cause little erosion, while wastes that are high in suspended solids will be much more erosive. Since our baseline interior tank-corrosion data were obtained from service station tanks, we assume that this data does not already account for erosion, for petroleum products are generally non-erosive.

We modeled erosion by adding the erosion rate to the interior corrosion rate. Although we did not model erosion as a localized process, we used it to augment both the localized and the generalized interior corrosion rates. We did this because in both cases our baseline data had applied only to non-erosive fluids.

The erosion rates which we used are listed in Table 25. Based on the fraction of suspended solids, this table distinguishes between three types of fluids: non-erosive, moderately erosive, and highly erosive. Most of the wastes under consideration in this study will be non-erosive, but a few sludges may be moderately or even highly erosive. The erosion rates in Table 25 are appropriate only if the fluid is always in motion. Thus, these values may be applied directly to continuous treatment tanks, but for other system the erosion rate must be multiplied by f, the fraction of the time during which fluid motion occurs in the component under consideration. Because fluid motion is not as rapid in tanks as it is in pipes, we have not modeled erosion in tanks. Future versions of our model, however, may be revised to account for turbulence beneath the fill pipe.

4.9 Gasket Disintegration

Gaskets gradually disintegrate due to the combination of chemical attack and erosion. We have modeled gasket aging as an erosion-like process with a baseline disintegration rate between 0 and 50 mils/year. Since we believe that lower disintegration rates are more likely, we use the following empirical distribution:

Cumulative Probability	Gasket Disintegration rate (mils/yr)
0.00 to 0.77	FNU(0,12.5)
0.77 to 0.83	FNU(12.5,25)
0.83 to 1.00	FNU(25,50)

Because gaskets can trap or absorb fluid, this disintegration process continues even when fluid is not present in the pipe. Therefore, we assume that the fraction of time when fluid is present is irrelevant for this type of failure.

Gasket disintegration may be greatly accellerated by incompatability between the waste and the gasket (EPA, Case Study No. 4, 1984). We account

TABLE 25. EROSION RATES FOR TANKS, PIPES, AND PUMPS

Component	Erosion rate (mils/year)		
	Non-erosive fluid (<1 ppm solids)	Moderately erosive fluid (between 1 and 10,000 ppm solids)	Highly erosive fluid (>10,000 ppm solids)
Tanks	0	FNU(0,5)	FNU(5,10)
Pipes	0	FNU(0,5)	FNU(5,10)
Pumps	FNU(0,10)	FNU(0,10)	FNU(10,20)

for this possibility by multiplying our baseline disintegration rates by a random number x sampled from FNU(1,20). If x is low, the gasket is compatable with the waste; if x is high, the gasket disintegrates unusually quickly.

A gaskets fails when its thicknesses reaches zero. Since a gasket is a flat, washer-like disk, the point of attack will be at its inside edge, which initially will be flush with the interior surface of the pipe. The gasket will fail when the difference between its inner and outer radii reaches zero. For gaskets for 2" pipes, this initial difference is 1.06 inches; for gaskets for 4" pipes, it is 1.44 inches (Perry and Chilton, 1973). Thus, gaskets can fail as early as year 2, or they may last for the entire lifetime of the facility.

4.10 Hole Sizes and Locations

Whenever a release occurs, the Monte Carlo model interrupts the fault tree sampling process to determine the release rate from the new leak. The first step in this procedure is to set the dimensions of the hole through which the fluid is leaking.

Hole sizes for all relevant failure events are given in Table 26. For most events, these hole sizes are stochastic and are determined by sampling the distributions listed in the table. For overflows, however, hole size is not a limiting factor in determining the loss rate. These loss rates are instead determined by the rate at which fluid is being pumped into the tank. Similarly, losses from external catastrophes are determined by the volumes of fluid present in the tank at the time of the catastrophe. For these events, therefore, Table 26 does not include hole sizes, but instead identifies the other factors (such as tank capacity) that determine the loss rate.

Hole size alone does not determine the leak rate. The density and viscosity of the waste are also important factors, as are the operating pressure inside the failed component and the nature of the medium into which the leak occurs. Two of these factors, density and viscosity, are determined

TABLE 26. INITIAL HOLE DIMENSIONS AND HOLE LOCATIONS FOR VARIOUS CLASSES OF FAILURES

Type of Failure (with event label)[1]	Dimensions of Hole (in inches)	Location of Hole
CORROSION HOLES		
● Tanks		
- Localized exterior corrosion (T1121)	diameter = B(1/64, 1/32, 1/4)	Bottom of tank
- Localized interior corrosion (T1123)	diameter = B(1/64, 1/32, 1/4)	Bottom of tank
- Generalized corrosion (T1127)	diameter = B(1/64, 1/32, 1/4)	Bottom of tank
● Pipes		
- Localized exterior corrosion (B13)	diameter = B(1/64, 1/32, 1/4)	Midpoint of pipe
- Localized interior corrosion (B13)	width = FNU(.1, .25) length = FNU(1, 10)	Midpoint of pipe
- Generalized corrosion (B13)	width = FNU(.1, .25) length = FNU(1, 10)	Midpoint of pipe
● Pumps		
- Localized exterior corrosion (A2116)	diameter = B(1/64, 1/32, 1/4)	Pump outlet
- Localized interior corrosion (A2116)	diameter = B(1/64, 1/32, 1/4)	Pump outlet
- Generalized corrosion (A2116)	diameter = B(1/64, 1/32, 1/4)	Pump outlet

TABLE 26. INITIAL HOLE DIMENSIONS AND HOLE LOCATIONS FOR VARIOUS CLASSES OF FAILURES (Continued)

Type of Failure (with event label)[1]	Dimensions of Hole (in inches)	Location of Hole
OTHER LEAKS AND RUPTURES (including installation damage)		
• Tanks (T1124)		
- seam leak (75% of cases)	width = FNU(0, 1/16) length = FNU(0, 60)	Bottom of tank
- major rupture (25% of cases)	width = FNU(0, 3) length = FNU(3, 36)	Bottom of tank
• Pipes (B11)	width = FNU(1, .25) length = FNU(1, 10)	Midpoint of pipe
• Flanges (B121)	width = FNU(0, 1/8) length = FNU(0, 50% of flange circumference	Varies with tank size, location, configuration, and process for which tank is used. See Appendix D.
• Gaskets (B122)	width = FNU(0,1/8) length = FNU(0, 50% of gasket circumference	Varies with tank size, location, configuration, and process for which tank is used. See Appendix D.
SECONDARY CONTAINMENT BREACHES		
• All secondary containment components[2]	Large enough to allow entire spill volume to escape before remedial action can be taken.	Lowest elevation in secondary-containment system, allowing the entire spill volume to escape.

TABLE 26. INITIAL HOLE DIMENSIONS AND HOLE LOCATIONS FOR VARIOUS CLASSES OF FAILURES (Continued)

Type of Failure (with event label)[1]	Dimensions of Hole (in inches)	Location of Hole
OTHER LOSS MECHANISMS		
• External catastrophe (all ANUCAT events)	Large enough to lose entire contents of tank.	Bottom of tank
• Overflow through vent or over sides of open-topped tank (A210 or A211)	Large enough that the overflow rate equals the rate at which fluid is being pumped into the system.	Top of tank
• Strainer drain left open (A11111)	Large enough that the spill rate equals the pumping rate	At location of pump
• Pump drain left open (A11112)	Large enough that the spill rate equals the pumping rate	At location of pump
• Flexible hose ruptures (A1112)	Leak rate = FNU(0, pumping rate)	At midpoint of hose
• Loose flexible hose connection (A1115)	Leak rate = FNU(0, pumping rate)	At tank's pump-out port

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[1] These labels correspond to the labels in the fault trees. They are also used in Appendix A. That Appendix explains the derivation of these hole sizes.

[2] If a system contains two secondary containment systems (such as a vault with a synthetic liner), both must fail before a release can occur.

by the identity of the waste, and will be the same for all leak locations. Similarly, the nature of the medium into which the leak occurs will be determined by the choice of backfill material, and will be the same for all underground leaks. The operating pressure at the site of the hole, however, varies with the hole's location. Table 26 identifies the locations where we have assumed each of the possible leaks or ruptures occur. From these location assumptions the operating pressures can be calculated according to standard engineering formulas. These formulas are too complex to present here, but have instead been included in Appendix A. These formulas are dependent on design factors (such as average fluid depth, pressure added by the pump, or the relative locations of tanks and pipes) which are also too complex to present in the main body of this report. These design details are given in Appendix D.

Most of the hole sizes listed in Table 26 are self-explanatory. Corrosion holes and secondary-containment breaches, however, require additional discussions.

Corrosion Holes. As Table 26 indicates, we have assumed that corrosion holes in tanks, pumps and above-ground pipes are generally circles, ranging in initial diameter from 1/64" to 1/4". We also use this size distribution for exterior corrosion holes in below-ground pipes. Due to the combination of soil corrosivity and the action of flowing fluid, however, we have assumed that interior and generalized corrosion holes in pipes are larger and more elongated, ranging in initial size from .1" x 1" to .25" x 10".

These hole sizes apply to new holes. With time, however, these holes will grow larger and larger until eventually their leak rates become large enough to be detected. We model the growth of corrosion holes by increasing the hole's radius at the end of each model year. For localized exterior corrosion failures, we assume that the hole continues to grow according to localized exterior corrosion but is now subject to attack from the inside as well. Thus, its hole growth rate is the sum of the generalized exterior corrosion rate, the generalized interior corrosion rate, and the erosion rate. We apply this growth rate to the hole's radius because corrosion will occur simultaneously on all parts of the hole's circumference. Based on similar reasoning, we assume that localized interior corrosion holes will grow at the sum of the localized interior corrosion rate, the erosion rate, and the generalized exterior corrosion rate, while generalized corrosion holes in tanks will grow at the sum of this generalized exterior and generalized interior corrosion rates, plus erosion. Due to the combination of soil corrosivity and the action of flowing fluid, however, we assume that generalized corrosion holes will grow rapidly, doubling in length and width each year until they are either detected and repaired or until the entire bottom of the tank has corroded.

Secondary Containment Breaches. Secondary containment breaches are also included in Table 26. For our present version of the model, we have assumed that a breach in the secondary-containment system will result in total non-containment. In practice, fluid might drain through the breach slowly enough that an emergency clean-up could be arranged in time to prevent a release of the entire volume, but we have made the conservative assumption that this is unlikely.

4.11 Leak-Rate Calculations

Leak rate formulas depend on whether the leaking components are above-ground or below-ground. For above-ground leaks (or leaks from underground tanks in vaults), the leakage occurs into an air environment, and the Bernoulli equation applies. According to this equation:

$$Q = .6A(2gz)^{.5} \qquad (4.1)$$

where

Q = the leak rate;

$.6$ = a coefficient appropriate for sharp-edged orifices;

A = the area of the crack or hole;

g = the accelleration due to gravity; and

z = the equivalent static hydraulic head (i.e., the equivalent height of the fluid surface above the hole, taking into account pressure additions due to pumps, or losses due to friction or suction when fluid is flowing through pipes). This is calculated according to the operating-pressure equations in Appendix A.

For underground leaks, however, the surrounding soil or backfill material will impede the flow of fluid, dramatically reducing the leak rate. In these circumstances, the Bernoulli equation no longer applies.

Unfortunately, there are no textbook formulas directly applicable to losses from underground tanks. Thus, we were forced to develop our own model for soil impedance, basing it on published studies of packed columns and fluid beds. The derivation of this model is contained in Appendix A. The final equation is:

$$Q = \frac{-B + (B^2 - 4AC)^{.5}}{2A} \text{ (Area)} \tag{4.2}$$

where

Area = The area of the hole

$$A = \frac{1.75\ (1-E_m)}{E_m{}^3} \frac{\varphi}{\phi_s d_p}$$

$$B = \frac{150\ (1-E_m)^2 \mu}{E_m{}^3\ (\phi_s d_p)^2}$$

$$C = \frac{-\Delta P}{L} g_c$$

in which

E_m = void fraction of the soil particles; (i.e. E_m is the ratio of the total void space to the volume occupied by the soil particles themselves)

φ = density of the fluid;

ϕ_s = sphericity of the soil particles;

d_p = average diameter of the soil particles;

μ = viscosity of the fluid

ΔP = the pressure drop between the inside of the hole and the surrounding soil; and

g_c = a conversion factor which is 1 in metric units and 32.17 in English units;

L = the distance required for leaking fluid to disperse (i.e. for its pressure to drop to that of the surrounding soil).

Our model included four basic types of backfill: gravel, sand, silt and clay. The relevant parameters for each of these soil types are presented in Table 27. The basic soil parameters were readily obtainable from hydrogeolo gic texts, but dispersion distances for underground leaks have never been published. The figures presented in Table 27 are therefore only estimates based on our own engineering judgement. In making these estimates, we began by noting that for cylindrical fluid beds, the dispersion length is linearly related to the bed diameter (Perry and Chilton, 1973). We assumed that a similar linear relation carried over to the conical or wedge-shaped dispersion patterns likely from corosion holes and underground cracks, respectively. Thus, the dispersion-length figures presented in Table 27 are given as multiplicative factors of hole diameter (for circular holes) or crack width (for elongated cracks). We further assumed that the dispersion length will be larger for a crack than it will be for a hole with a diameter equal to the crack's width. We made this assumption because fluid leaking from a hole will be able to disperse in all directions, but fluid leaking from an elongated crack will only be able to disperse in directions perpendicular to the crack. In addition, we noted that fine-grained materials like silt and clay offer a greater resistance to fluid flow than do coarse-grained materials like sand and gravel. Thus, dispersion lengths will be smaller for fine-grained materials than they will be for coarse-grained materials. These observations are reflected in the dispersion-length coefficients listed in Table 27.

The precise arithmetic values for these coefficients were difficult to determine. We based our choices of coefficients on our engineering assessment of published tank failure case studies (see Appendix C for sum-

Table 27. SOIL PARAMETERS FOR UNDERGROUND LEAKS

Parameter	Backfill Material Gravel	 Sand	 Silt	 Clay
DISPERSION LENGTH				
• Circular holes (diameter d)	100 x d	20 x d	7.5 x d	2 x d
(maximun value)	(100cm)	(20cm)	(7.5cm)	(2cm)
• Elongated cracks[1] (width w)	100 x w	40 x w	10 x w	4 x w
(maximum value)	(100cm)	(40cm)	(10cm)	(4cm)
VOID FRACTION[2]	.50	.53	.75	.95
PARTICLE SIZE[2]	9.4	.25	.064	.002
SPHERICITY[2]	.70	.65	.34	.075

---

[1] Cracks will have a longer dispersion length than holes because dispersion can only occur in directions perpendicular to the crack.

[2] Source: Kunii and Levensaul (1969)

maries of 21 of these case studies). From these case studies, we concluded that a moderately large (1 cm) hole in a 10,000-gallon tank buried in sandy soil should produce a leak rate of approximately 1,500 gallons per month. This will occur (assuming 4 feet of hydraulic head) if the dispersion length is 20 cm, i.e. if the dispersion length coefficient is 20. We then chose other dispersion length coefficients to be consistent with both that value and our assumptions about the effects of hole shape and soil particle size. In addition, we have assigned maximum values to each dispersion-length coefficient. These maximum values, which are listed in Table 27, are the maximum lengths that our formulas would predict for hole diameters or crack widths of 1 cm.

As equation (4.2) and Table 27 indicate, our underground leak-rate model is quite complex, depending on several variables. The most important variables, however, are the soil parameters and the hole size. Figures 26A through 26D examine the effects of these parameters by plotting leak rates versus hole sizes for a 10,000-gallon storage tank in each of the four representative soils. These graphs show that leak rates are highest for gravel, and lowest for clay, as would be expected. In addition, these graphs show that despite the complexity of equation (4.2), leak rates are almost linearly dependent on hole diameters, at least for holes greater than 1/8 inch in diameter. This linear relation results because an increase in hole size has two opposing effects on leak rates: it increases leakage by increasing the hole's surface area; and it decreases the leak rate by lengthening the dispersion distance. According to Figures 26A through 26D, the net result of these two effects is that leak rates are almost linearly related to hole diameters.

4.12 Leak Detection

Once a leak develops, it will continue until it is detected. Detection may occur immediately, or it may be delayed for weeks or even months. If the leak is small enough, it may never be detected.

We have considered 9 possible leak detection options. These options, which may be used in any combination are:

FIGURE 26A. THE EFFECT OF HOLE DIAMETER ON LEAK RATES IN CLAY

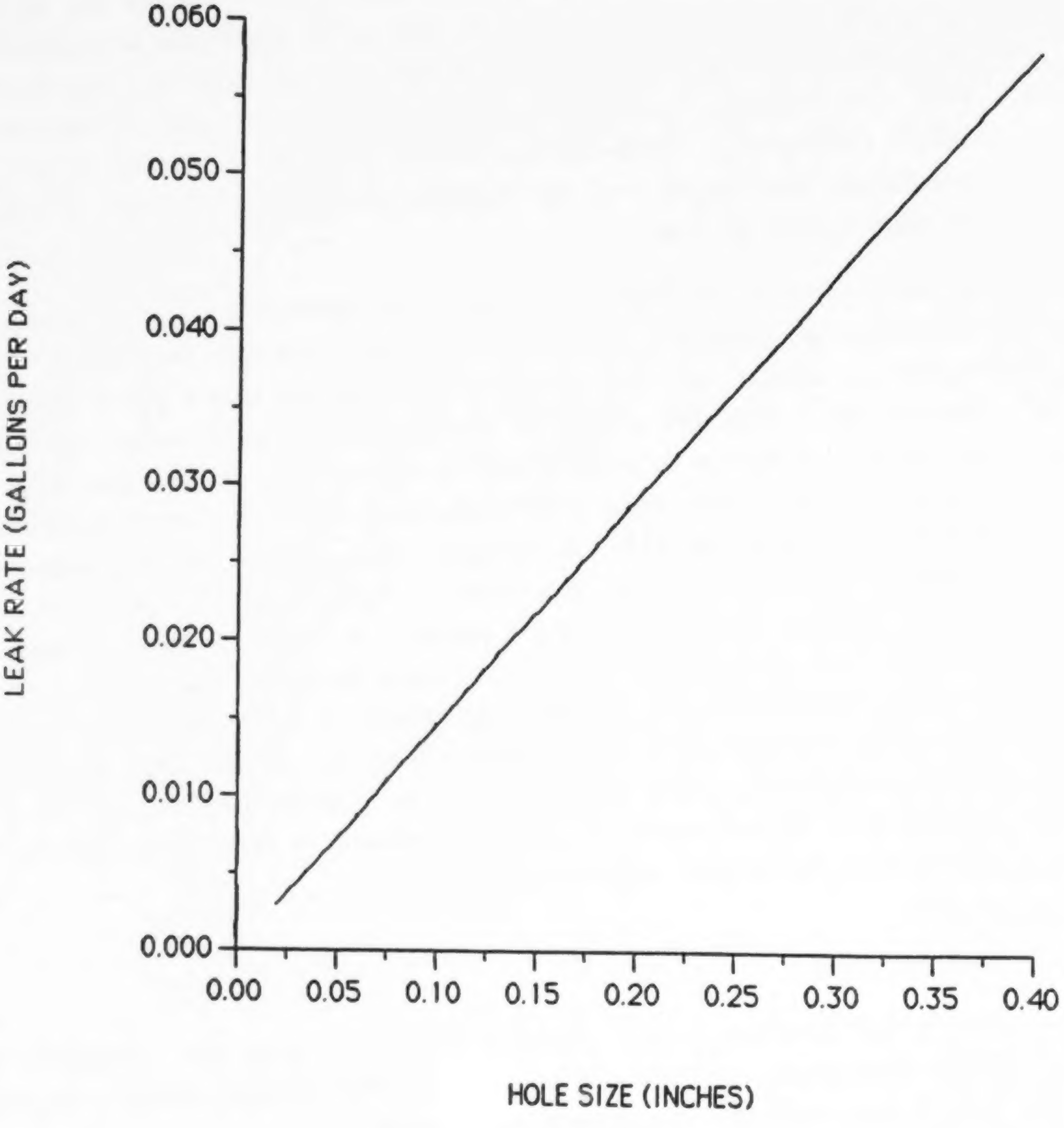


FIGURE 26B. THE EFFECT OF HOLE DIAMETER ON LEAK RATES IN SILT

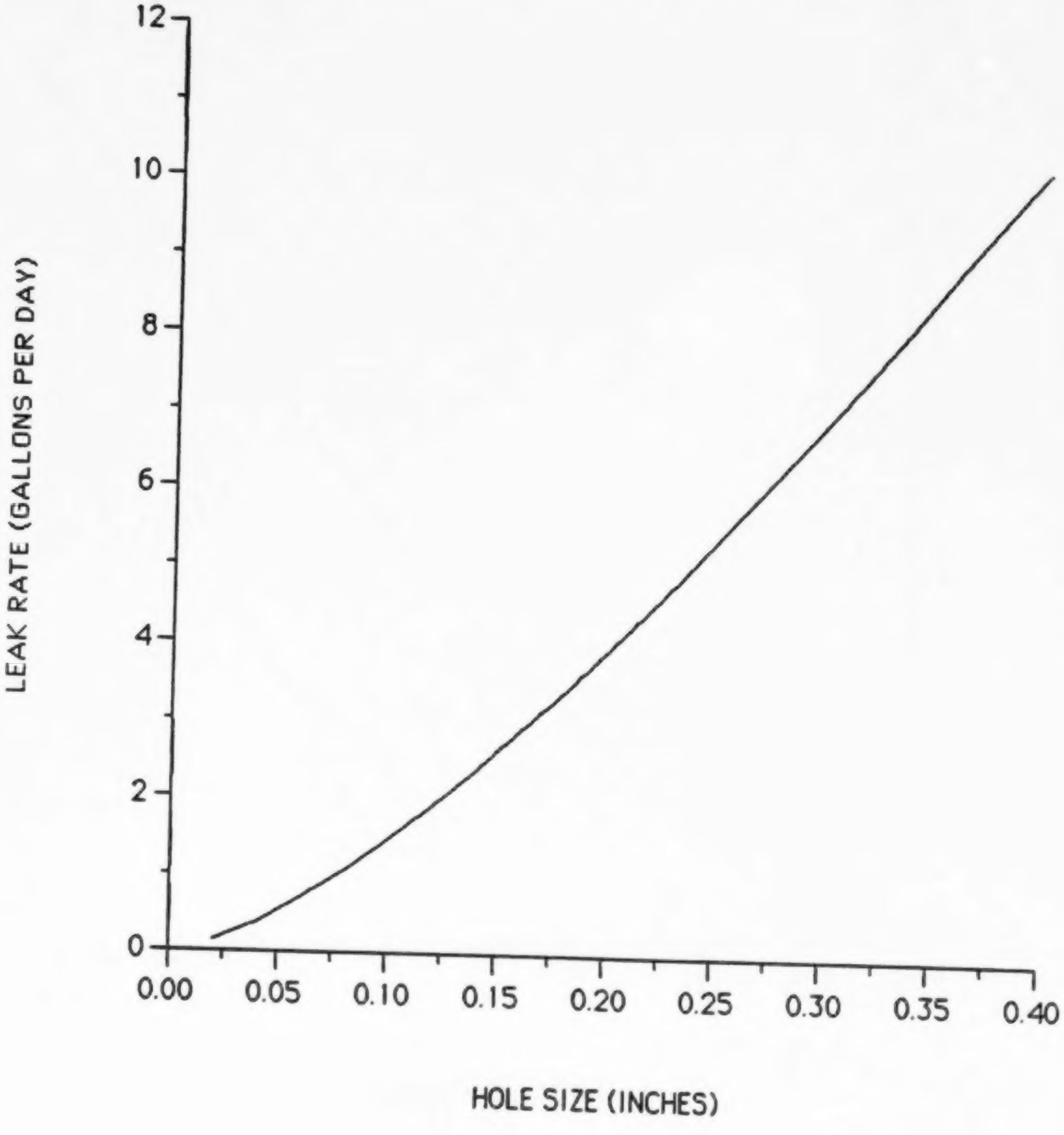


FIGURE 26C. THE EFFECT OF HOLE DIAMETER ON LEAK RATES IN SAND

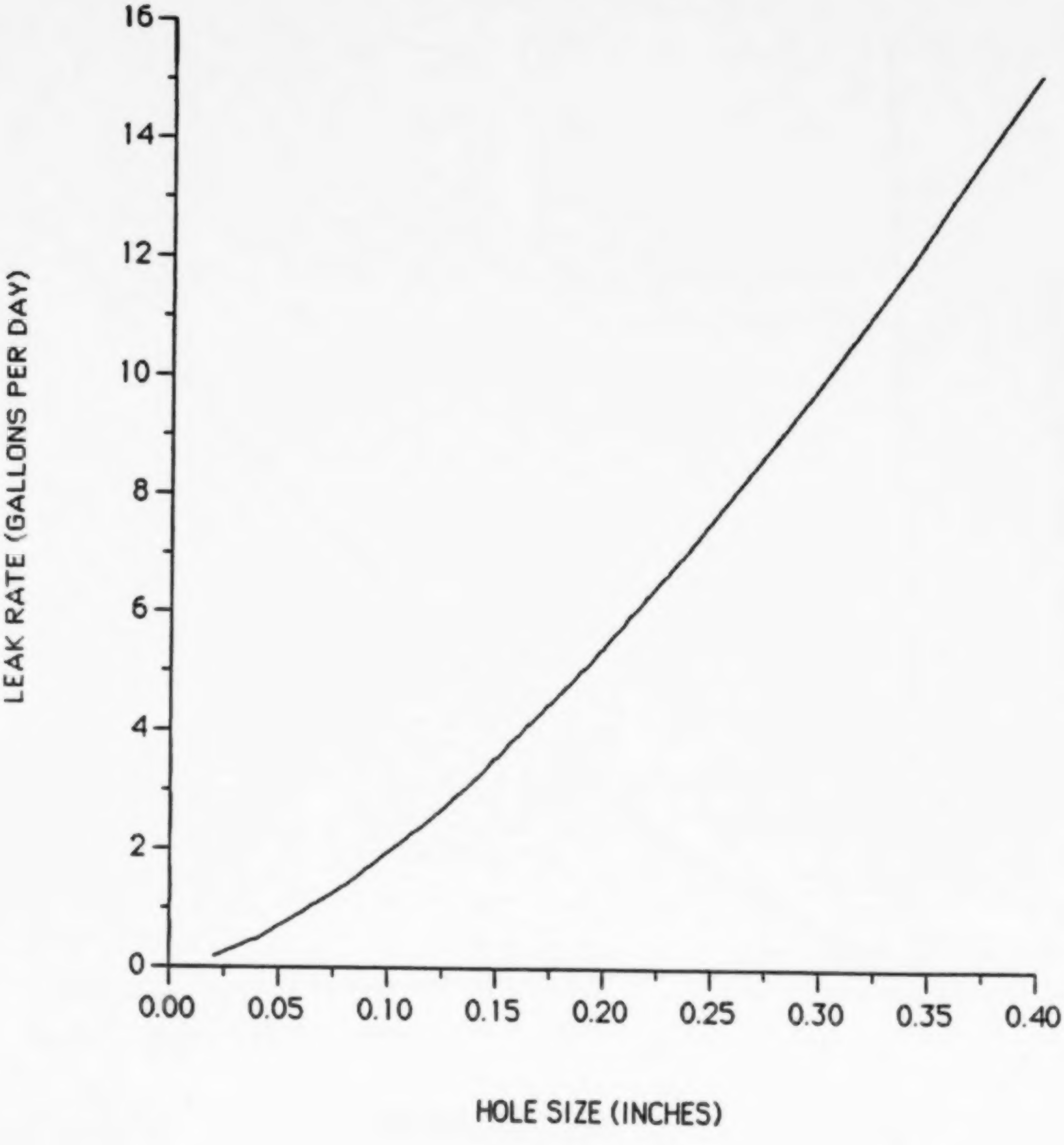
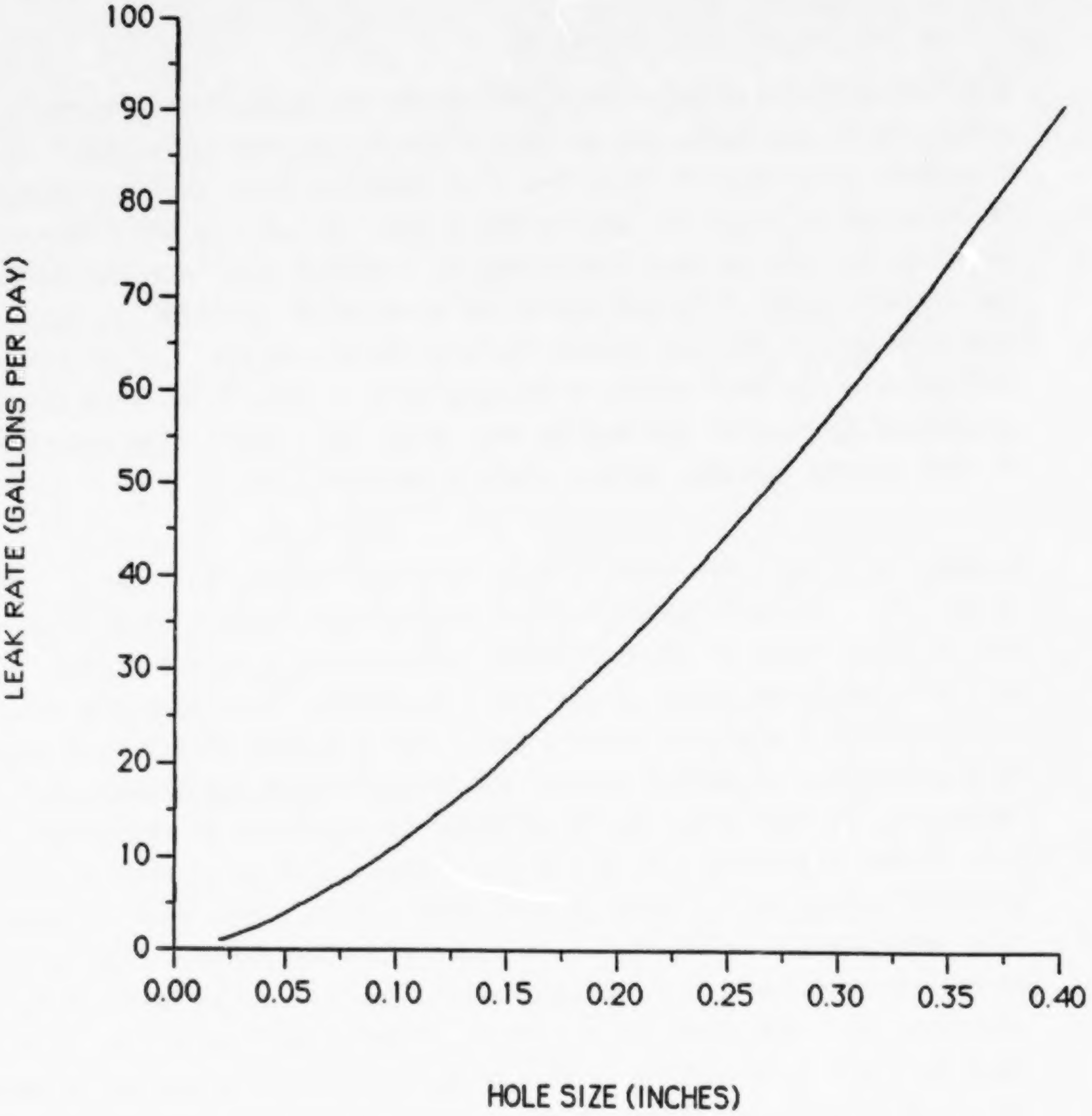


FIGURE 26D. THE EFFECT OF HOLE DIAMETER ON LEAK RATES IN GRAVEL



- Visual inspection,
- Inventory monitoring,
- Vapor wells,
- Interstitial monitoring,
- U-tubes,
- Pollulert monitoring,
- Continuous pipe monitoring,
- Groundwater monitoring, or
- Unsaturated zone monitoring.

With the exception of groundwater monitoring and unsaturated zone monitoring (which the Agency has decided to model using the contaminant transport subroutines of ICF's Tank Risk Model) we have incorporated each of these options into our Tank Failure Model. In modeling these leak detection systems, we have been primarily concerned with three parameters: the minimum volume of release which can be detected, the time lag until detection occurs, and the probability that the system will fail to detect a release which is large enough to be detectable. Table 28 presents these parameters for each of the modeled leak detection systems. The remainder of this section explains these systems in greater detail.

Visual Inspection. Our model permits the simulation of two types of visual inspection. One of these is a casual "walk-around" inspection which we assume occurs daily at all facilities. The other is a more thorough periodic inspection, which is optional. Generally, this inspection is carried out on a weekly or monthly basis, but the model allows us to specify any desired inspection cycle. The probability of detecting a leak depends on the leak rate, and is different for each type of inspection. We have assumed that casual inspection (or normal operating routine) will always be sufficient to detect a leak larger than a slowly running faucet (approximately 100 cm^3/minute). For leaks with rates between 10 drops per minute (approximately .5 cm^3/minute) and 100 cm^3/minute, we have assumed that there is a 50% probability of detection by casual inspection. Smaller leaks will not be detectable by this method. Periodic inspection, however, will have a 95% chance of detecting any above-ground leak.

The time lag between the onset of a leak and its detection depends on the size of the leak and when during the inspection cycle the leak begins. In

TABLE 28. LEAK DETECTION PARAMETERS

Leak Detection System	Threshold Level Necessary for Detection	Time Lag Until Detection	Failure Probability
VISUAL INSPECTION			
• Casual	100 cm^3/min	FNU(.25,60) min	0
	.5 cm^3/min to 100 cm^3/min	FNU(0,24) hrs	.50
	<.5 cm^3/min	Not detectable	1.00
• Careful	No limit	FNU(0,7) days	.05
• Visual detection of overflows	No limit	FNU(0, fill time)	0
• Visual detection of pump drain or strainer spills	No limit	FNU(0, fill time)	0
• Visual detection of flexible hose ruptures or loose connections	No limit	FNU(0, pump-out time)	0
INVENTORY MONITORING			
• Casual (daily)	Determined by user input (0-100% of tank capacity).	FNU(0,48) hours	0
• Weekly, monthly, or at pump-out	Determined by user input (0-100% of tank capacity).	Depends on when during inspection cycle leak begins.	0

TABLE 28. LEAK DETECTION PARAMETERS

Leak Detection System	Threshold Level Necessary for Detection	Time Lag Until Detection	Failure Probability
TIGHTNESS TESTING	Determined by user input (generally .10 gal hr).	FNU(0,interval between tightness tests).	0
VAPOR WELLS	Determined by user input (250 ppm is typical).	Given by solving Thibodeaux's equation for t.	.10
U-TUBES	Conservatively estimated as the volume of fluid needed to saturate all of the soil between the tank bottom and the tubes.	Depends on the porosity at the backfill, depth to the U-Tubes, soil permeability, soil moisture content, leak rate, and identity of the waste.	0
POLLULERT MONITORING	Conservatively estimated as the volume of fluid needed to saturate all of the soil between the tank bottom and the water table.	Depends on the porosity at the backfill, depth to the groundwater, soil permeability, soil moisture content, leak rate, and identity of the waste.	0
CONTINUOUS PIPE MONITORING	0.2 gal/hr.	0	0
INTERSTITIAL ALARMS	no limit	Detection is immediate if the alarm functions.	.10
LEAK DETECTORS IN VAULTS	no limit	FNU (1,12) hrs	.10

general, leaks detected by casual inspection will be detected in FNU(0,24) hours, leaks detected by weekly inspection will be detected in FNU(0,7) days, and leaks detected by monthly inspection will be detected in FNU(0,30) days. For leaks in excess of 100 cm^3/minute, however, detection will be in FNU(.25,60) minutes.

Visual inspection will also lead to detection of overflow or accidental spills. Because we assume that the operator is likely to observe these types of leaks without taking a walk-around inspection, we assign them shorter detection periods. These detection periods are listed in Table 28.

Inventory Monitoring. Inventory monitoring programs are designed to detect shortfalls in the amount of fluid contained in a tank by comparing the actual volume to that which is predicted by tallying fill volumes and discharge volumes. This type of leak detection is useful only for storage and accumulation tanks, however, for the short time period between pump-outs for treatment tanks (even continuous systems are emptied once a day) means that any leaks large enough to cause a detectable inventory shortfall would also be large enough to be immediately obvious to the operator.

In theory, the detection threshold for inventory monitoring depends on the monitoring frequency and the care with which records are maintained. If monitoring is carried out frequently, with accurate records, it is possible to apply statistical techniques to detect relatively low loss rates from product storage tanks. These techniques have not been developed for above-, in-ground, open-topped, or hazardous waste tanks. Since there is no reliable method for hazardous waste materials of the aforementioned tank types, we have assumed that monitoring is carried out casually, with a much higher detection threshold than would apply for more sophisticated inventory control programs. This is the level of inventory control we expect to find at existing hazardous waste tank facilities.

We have modeled two types of inventory monitoring. The more sophisticated of the two is daily monitoring. This type of monitoring involves a daily inspection of the fluid level, but requires no record-keeping or statistical analysis. The detection threshold for this type of monitoring is specified as a percentage of tank capacity, and is set by user input. Because of the casual nature of this type of monitoring, we recommend the use of a fairly large detection threshold, perhaps 10-25% of tank capacity. This threshold applies to the sum of all losses occurring between monitorings. Thus, if a tank has two leaks, neither of which alone would be large enough to trigger detection, their sum may nevertheless exceed the threshold level, and both leaks would then be detected and repaired.

The second type of inventory monitoring is periodic monitoring. For this type of monitoring, the operator periodically computes the expected volume of waste in the tank and compares it to the actual volume. If he detects a shortfall, he assumes that a leak has developed. The detection threshold for this type of monitoring depends on the accuracy of the operator's records and the care with which he measures the volume of waste contained in the tank. For simplicity, we specify this detection threshold is a fraction of tank capacity. This fraction is determined by user input. Because we are assuming that this is a fairly casual type of inspection carried out by poorly trained operators, we recommend the use of a fairly large detection level (at least 10% of tank capacity).

The detection lag for this type of monitoring depends on when during the inspection cycle the leak begins. If the leak begins early, there is a higher chance that the accumulated loss volume will be large enough for detection at the next scheduled inventory reconciliation. Otherwise, even if the leak rate is fairly rapid, the leak may not be detected until the following reconciliation. We account for this possibility by randomly setting the time during the monitoring cycle when the leak develops. The minimum detection delay is therefore zero (for a large leak developing immediately before the inventory is reconciled), while the maximum is two full inspection cycles (for a leak that is barely large enough to be detected and which begins too late in the monitoring cycle to be detected at the first inventory reconciliation). The interval between inventory reconciliations is set by user input, and may range from one month to the entire period between pump-outs.

Vapor Wells. Vapor wells detect leaks by sensing hazardous waste vapors in the soil near the leaking component. This detection method is appropriate for volatile waste streams. According to Thibodeaux (1979), the concentration of hazardous waste vapor at an underground distance z from the source is given by:

$$C = C_0\left[1\text{-erf}\left(\frac{z}{4Dt(\epsilon/1.73)}\right)\right]$$

where

C = the concentration of the contaminant at the sensor

C_0 = the concentration of the contaminant at the source (we assume that the air there is saturated with the vapor)

z = the distance from the source to the sensor

D = the diffusivity of the contaminant in air

t = the elapsed time since the leak began

ϵ = the porosity of the soil

erf = the standard Gaussian error function

We obtain the time to failure by setting C equal to the detection threshold of the vapor sensor (150 ppm for a Sensidyne detector). We then solve Thibodeaux's equation for t, the elapsed time until the concentration at the sensor reaches this level. This time t is the detection lag; C is the detection threshold.

Thibodeaux's equation is based on the assumption that there is enough liquid at the source to keep the nearby air saturated. The model checks this assumption by calculating the radius of the smallest sphere that could contain the vapor if the entire leak evaporated. If that sphere is not large enough to reach the sensor, then no detection has occurred regardless of the results of the Thibodeaux equation.

Vapor wells are not 100% effective. We assume that they have a 10% per-demand probability of failure. If the sensor fails, the leak will continue for 1 month, at which time we assume that the sensor will be repaired and the leak will be detected.

Tightness Testing. Tightness testing is capable of detecting very slow leaks in either tanks or pipes. In theory, because tightness tests use careful surface-level measurements to detect leaks by detecting minute changes in fluid level, the sensitivity of this leak detection technique should be inversely related to the size of the tank. Because the manufacturers claim the same detection limits for all tank sizes, however, we have not attempted to adjust for tank size. Instead, we have left the threshold level as a user input, so that sensitivity analyses may be performed easily. We have also allowed the testing schedule to be determined by user input.

Tightness testing has not been proven reliable for hazardous wastes to achieve suggested reliability levels. As a consequence, tank facilities may need to replace the tank fluid with water to perform such a test. We will assume that our tightness testing results represent the use of water, not hazardous waste. As a result, our costs must include cleaning the tank and possibly the installation of a manhole.

U-Tubes. U-tubes are porous tubes running beneath an underground or in-ground tank. Usually, these tubes are located one or two feet beneath the tank, but the the model allows us to specify any desired depth. These tubes collect leaking waste and channel it to an underground sump where it can be monitored at any specified interval (generally weekly or monthly). As an alternative, U-tubes can be continuously monitored by including a liquid sensor in the sump.

The detection lag for U-tubes is a combination of two factors: the time lag until the waste reaches the tubes, and the time lag between the arrival of the waste in the sump and its detection there.

The detection lag for the percolation of waste through the intervening backfill is given by the following expression (EPA, Liner Location Report, 1984):

$$t = \left[\frac{z(\xi - \theta_i)}{(dQ/dt)} \right] \left(\frac{dQ/dt}{K} \right)^{.25}$$

where

t = the time required for leaking waste to penetrate to the U-tubes

z = the depth of the U-tubes beneath the tank

dQ/dt = the leak rate

ξ = the porosity of the backfill

θ_i = the moisture content of the backfill (before the spill)

K = the permeability of the soil to water

The values of K, ξ, and θ_i for each of our four types of backfill are listed in Table 29. For U-tubes lying beneath 1 foot of sand backfill, it will take 32 hours for waste to reach the tubes from a 1-gallon-per-day leak.

TABLE 29. HYDROGEOLOGIC PARAMETERS FOR VARIOUS SOIL TYPES[1]

Soil Type	Porosity Porosity	Moisture Content	Permeability (cm/sec)[2,3]	Residual Saturation
Gravel	0.25	.09	$1\text{x}10^{-2}(.4^{N})C$	1.0
Sand	0.35	.09	$1\text{x}10^{-2}(.6^{N})C$	1.0
Silt	0.35	.27	$1\text{x}10^{-8}(.02^{N})C$	1.0
Clay	0.5	.30	$1\text{x}10^{-8}(.12^{N})C$	1.0

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[1] Source: Fetter, (1980).

[2] C is an adjustment factor for viscosity and density variations:

$$C = \frac{\text{water}}{\text{waste}} \times \text{specific gravity of waste}$$

where denotes viscosity

[3] N=1 if petrochemical, otherwise N=0.

We have conservatively estimated the detection threshold for U-tube monitoring as the volume required to saturate all of the soil between the tank bottom and the U tubes. This volume is given by the following formula (EPA, Liner Location Report, 1984):

$$Q = z (\xi)(\theta_p)(A)$$

where

Q = the threshold release volume,

θ_p = the residual saturation of the backfill; and

A = the cross-sectional area of the leak source

The value of θ_p depends on the nature of the backfill. Representative values of θ_p are included in Table 29 for aqueous wastes and toluene. For U-tubes located 1 foot beneath a horizontal, 10,000-gallon tank, this detection threshold for an aqueous waste is 445 gallons.

In addition, the detection threshold for U-tube monitoring is also governed by the sensitivity of the technique used to monitor the sump. We have assumed that this threshold is insignificant compared to the threshold volume required for the liquid to initially reach the U-tubes. We have also assumed that the sump monitoring method has a near-zero failure rate.

Pollulert Monitoring. A pollulert system is a monitoring device located in a well reaching to the water table. This monitoring system detects leaks by sensing organic wastes floating on top of the water table. We have modeled Pollulert systems in the same way as we have modeled U-tubes, except that for Pollulert systems the sensor is always monitored continuously.

Continuous Pipe Monitoring. Continuous pipe monitoring systems use electrical sensors on the pipes to detect changes in soil conductivity caused by leaks. They can detect leaks as small as 0.2 gal/hr (Sobotka, 1984), and we assume that they will react immediately to detectable leaks. There are a variety of such pipe monitoring techniques, but the present version of our model has not attempted to distinguish among them.

Interstitial Alarms and Alarms in Vaults. Interstitial alarms are leak sensors placed between the walls of double-walled tanks or pipes. If either of the walls is breached, such an alarm will react immediately to the influx of waste (for breaches of the inner wall) or soil monitor (for breaches of the outer wall). This allows the operator to take the proper remedial action. In many cases, no waste will have been released to the environment because one of the walls will still be intact.

Alarms in vaults are similar, except that they are not sensitive enough to detect infiltrating soil moisture (otherwise they would also react to atmospheric condensation). Thus these alarms give immediate notice of breaches in the tank, but they give no notice of breaches in secondary containment. By detecting the leak from the tank, however, they prevent the leak from continuing undetected for long periods of time.

All types of alarms are subject to failure. Since interstitial alarms and alarms in vaults are physically very similar to high-level alarms, we have given them the same failure probability as we used for high-level alarms. This probability is 10% per demand. The derivation is presented in Appendix A under event MOALARM.

Remedial Action. Once a leak has been detected, the operator must take action to prevent it from continuing. Generally, such action requires that operating procedures be changed until the leak can be repaired. We have conservatively assumed that except for overflows, accidental spills, or external catastrophes, such remedial action requires 2 days to implement. Overflows and spills can be remedied immediately, however, and remedial action delays are irrelevant for external catastrophes because these events have already resulted in the loss of the system's entire contents.

5.0 RECOMMENDATIONS FOR ADDITIONAL RESEARCH

5.1 Possible Modifications to the Model

A complex simulation model such as ours is always open to refinements designed to increase the accuracy with which it reflects the complexities of the real world. Table 30 lists a number of refinements which we deem to be worthy of further consideration. Most of these changes could be implemented with very little effort. These easily implemented changes are:

- Improving our hole-size estimates for generalized exterior corrosion holes;
- Including erosion (beneath the fill pipe) in our tank model;
- Separate modeling of the above-grade and on- or below-grade sections of on-grade or in-ground tanks;
- Using a separate cathodic-protection system for each protected component;
- Allowing inspection and repair of coatings on above-ground tanks;
- Including sophisticated inventory-monitoring systems as a leak-detection option;
- Allowing the efficacy of careful visual inspections to vary with the leak rate;
- Including ultrasonic testing as a leak prevention option; and
- Modifying our pipe-rupture model to account for variations in pipe-length.

Other changes would require more effort, either because good data may be difficult to locate, or because these changes would require revisions of substantial segments of the computer code. Nevertheless, these changes are useful enough that we recommend that at least some of them be carried out. The details of these proposed revisions are given in Table 30, which lists the present modeling approach, the proposed revision, and the effects of the proposed change. It also discusses the difficulties likely to be encountered in implementing each of these changes. These changes are:

- Modeling the possibility of multiple corrosion holes for exterior tank corrosion;

TABLE 30. CHANGES WHICH MAY BE INCORPORATED INTO FUTURE VERSIONS OF OUR MODEL

Model Element	Present Modeling Approach	Proposed Revision	Effect of Proposed Revision	Difficulty of Implementation
TANK CORROSION				
• Multiple localized exterior corrosion holes	We only model one localized exterior corrosion hole per failure incident.	Include the possibility of multiple corrosion holes.	This would increase leak rates.	Could be accomplished by assuming that tank corrosion is similar to pipe corrosion, and by applying the appropriate elements of the Rossum pipe corrosion model to tanks.
• Multiple interior corrosion holes	We only model one interior corrosion hole per failure incident.	Include the possibility of multiple corrosion holes.	This would increase leak rates.	Unknown
• Hole sizes for generalized corrosion holes	We use the same hole-size distribution as we use for localized corrosion holes.	Make these holes large and rapidly growing.	Would increase the leak rates.	We already make this distinction for pipes. We could easily use the same approach for tanks.
• Erosion	We do not model erosion of tanks.	Allow tanks to erode beneath the fill pipe.	Would increase the interior corrosion rate slightly.	We already model erorion in pipes and pumps. We could easily use the same approach for tanks.
• Effect of waste pH on tank corrosion	Our present corrosion rates are derived from data for gasoline, and therefore apply for normal environments.	Model acidic wastes as more corrosive.	Would substantially increase interior corrosion rates for tanks containing acidic wastes.	Would require additional library research.
• In-ground tanks and above-ground tanks on-grade	We only model corrosion for the below- or on-grade segments of these tanks. tanks.	Model the corrosion of both of these segments.	Would increase the number of corrosion failures for these tanks.	Requires only minor changes in the computer code.
PIPE AND PUMP CORROSION				
• Multiple interior corrosion holes	We only model one interior corrosion hole per failure incident.	Include the possibility of multiple corrosion holes.	This change would increase leak rates.	Unknown. Data might be very difficult to locate.
• Effect of waste pH on pipe corrosion.	Our present corrosion rates are derived from data for gasoline, and therefore apply for normal environments.	Increase the corrosity of acidic wastes.	This change would substantially increase interior corrosion rates for pipes containing acidic wastes.	Would require additional library research.

TABLE 30. CHANGES WHICH MAY BE INCORPORATED INTO FUTURE VERSIONS OF OUR MODEL (Continued)

Model Element	Present Modeling Approach	Proposed Revision	Effect of Proposed Revision	Difficulty of Implementation
PIPE AND PUMP CORROSION (Continued)				
• Time-to-failure distribution for localized exterior corrosion of underground pipes	We assume that the date of the nth failure is uniformly distributed between the time when the expected number of corrosion holes is n-1 and when it is n+1.	Double the probability that the n'th hole develops at time t.	This would assure that the nth corrosion hole develops by the time predicted by Rossum and would give the same number of expected releases as he predicts.	Simple.
CORROSION PROTECTION				
• Cathodic protection	We presently assume that all components of the tank system are connected to the same cathodic-protection system.	Use a different cathodic-protection system for each of the protected components.	This would reduce the number of components affected by a cathodic-protection system failure but would increase the number of systems subject to failure.	Fairly simple.
LEAK DETECTION AND SECONDARY CONTAINMENT				
• Coatings on aboveground tanks and pipes	We presently assume that like underground coatings, these coatings receive no maintenance.	Model the maintenance of such coatings.	This would increase the service life of aboveground coatings.	Fairly simple.
• Sophisticated inventory modeling (using statistical analysis of time-series data)	Not included in present model.	Include it as a leak detection option.	The model would be more flexible.	Simple—we have already modeled this leak detection method in another computer model.
• Casual inventory monitoring	We presently assume that the operator will take no action until the leak is confirmed by two successive days of shortfalls. Thus, we use a detection lag of FNU(24,48) hours.	Eliminate the assumption that the operator will await confirmation.	Reduces loss volume by changing the detection lag to FNU(0,24) hours.	Trivial.
• Careful visual inspection	We presently assume that this method has a 90% probability of detecting even the smallest leak.	Allow the effectiveness of this method to depend on the leak rate.	In our present model, this method is too effective for detecting very small leaks.	Trivial.

TABLE 30. CHANGES WHICH MAY BE INCORPORATED
INTO FUTURE VERSIONS OF OUR MODEL (Continued)

Model Element	Present Modeling Approach	Proposed Revision	Effect of Proposed Revision	Difficulty of Implementation
MISCELLANEOUS				
• Ultrasonic testing	Not presently included in the model.	Include this inspection option in the model.	Would allow the inspector to detect thin spots before corrosion holes develop.	Trivial.
• Pipe rupture	We presently assume that the probability of pipe rupture is independent of pipe length.	Let longer pipes be more vulnerable to rupture.	Would increase the probability of rupture for long pipes and decrease it for short pipes.	Simple, although it may be difficult to obtain authoritative documentation.
• Cracking of concrete tanks	The distribution used in our model was derived for tanks with 20-year design lives.	Let the time-to-failure distribution vary with design life.	Would substantially reduce the number of failures for concrete tanks designed for 30 or 40 years.	Depends on level of sophistication desired. Might require additional library research and might be difficult to document.

- Modeling the possibility of multiple interior corrosion holes for both tanks and pipes;
- Including the waste's pH as a parameter in our interior corrosion models for pipes and tanks;
- Changing our time-to-failure distribution for underground localized exterior pipe corrosion to eliminate a present bias in favor of belated development of corrosion holes; and
- Designing a more sophisticated model for the cracking of concrete tanks.

5.2 Caveats

There are other refinements which would be useful if adequate data could be found. Because such data are unlikely to be available, however, we have not included these refinements in Table 30. Instead, we will discuss them in this section as caveats.

Use of Uniform Corrosion Rates. Both our tank- and pipe-corrosion models are based on the assumption that localized exterior corrosion holes grow at constant rates throughout their life-spans. Thus, we have assumed that corrosion rates are independent of pit depth. Rossum's article, however, indicates that corrosion rates slow down as the pit surface area gets larger and as the pit fills with scale. Thus, pits grow rapidly at first, but slower later on. Since our corrosion rates are the averages obtained from .25-inch tanks (or .19-inch pipes), they still correctly predict dates of failure for pipes of these thick- nesses, but if Rossum's non-linear model is correct, our average corrosion rates are too rapid for thicker materials and too low for thinner materials. In addition, our attempts to combine generalized interior corrosion with localized exterior corrosion also result in delayed failure dates if Rossum's non-linear model is correct. This bias occurs because generalized interior corrosion effectively reduces the thickness of the component wall over the period of time during which corrosion is occurring.

As an example, consider a .25-inch tank with a 5-mil-per-year interior corrosion rate and an exterior corrosion time-to-failure of 25 years (obtained by sampling the PACE corrosion data). According to our model, this tank will have an exterior corrosion rate of 10 mils per year, for a combined corrosion rate of 15 mils per year. Under our uniform corrosion-rate assumption, failure will occur in 17 years.

Suppose, however, that the corrosion rate decreases with pit depth. A 25-year time-to-failure might then correspond to the following corrosion rates:

Years Since Onset of Corrosion	Annual Corrosion Rate
1-5	15 mils/yr
6-10	12 mils/yr
11-15	10 mils/yr
16-20	8 mils/yr
21-25	5 mils/yr

If this tank is now given a 5-mil/yr interior corrosion rate, failure will occur in year 14, somewhat earlier than the year-17 prediction obtained from the uniform corrosion example.

It should be noted that the above example is an extreme case. It involves both a very high interior corrosion rate and a 3-fold change in the annual corrosion rate with pit depth. And even with these extreme effects, it only alters the time-to-failure by 18% from that obtained from the purely linear approximation. This indicates that the model is fairly robust to non-uniform corrosion rates, at least as long as the tank wall-thickness remains at .25 inches. If the initial tank wall-thickness is substantially altered, however, the uniform corrosion-rate predictions are not as robust. Since non-uniformities have been observed for localized interior corrosion (Ishikawa, et al, 1981) as well as localized exterior corrosion (Rossum, 1968), future versions of our model could be improved by exploring these non-uniformities and incorporating them into the interior and exterior pit-growth models. Adequate data, however, might be very difficult to locate.

Baseline Corrosion Data for Tanks. The tank corrosion time-to-failure data is based on the PACE survey data. PACE obtained this data from three sources:

- Over a 6-month period in 1977, PACE requested its member companies to report leak incidents.

- During this same time period, PACE requested the member companies to report tank decommissionings. PACE then tested the decommissioned tanks for leaks.
- If one tank on a particular site was leaking or decommissioned, PACE also tested all other tanks on the same site.

The PACE survey is therefore a combination of two non-random samples, one of leaking tanks (and other tanks on the same site) and the other of decommissioned tanks (and tanks near them). The first sample is biased toward leaking tanks; the second is biased toward tanks old enough to be decommissioned. In addition, the second sample is biased toward non-leaking tanks, for in 1977, most gasoline storage tank decommissionings probably resulted from the closing down of non-profitable service stations, or the replacement of undersized tanks, rather than the removal of tanks that were known to be leaking.

The net effect of these two biases is unclear. The resulting time-to-failure distributions look reasonable, so the net bias is probably not severe. Nevertheless, the model could be revised if an unbiased time-to-failure survey becomes available.

Air Quality and Corrosion of Above-Ground Tanks and Pipes. Our above-ground exterior corrosion models do not take local air quality into account. Air quality, however, may be very poor in the vicinity of certain process tanks, and this poor air quality could substantially increase both the generalized and the localized exterior corrosion rates. Since our model does not include this effect, it does not presently apply to tanks or pipes located near process equipment which produces corrosive fumes. Future versions of the model could be generalized to take these effects into account if adequate data could be located.

Initial hole sizes for localized corrosion failures. We have assumed that localized corrosion holes initially range between 1/64 and 1/4 inches in diameter. This assumption is based on anecdotal data and personal observations. It could be improved if a better data set were available.

Corrosion hole growth rates. In our corrosion model, we have modeled corrosion holes as circles that expand in radius as continued corrosion consumes the surrounding metal. This model presents a good approximation of the behavior of corrosion holes, but a more sophisticated approach would be to model corrosion holes as hemispherical pits, growing at the appropriate corrosion rate. When failure occurs, the metal around the edges of such a hole would be very thin, and would corrode rapidly. We could account for this by allowing the corrosion hole to continue growing as an imaginary hemisphere, with the edges of the hole representing the points of intersection between the hemisphere and the tank wall. The effect of this would be to cause the corrosion hole to expand rapidly at first, then slower and slower. The growth rate, however, would always be somewhat higher than that predicted by our present model.

Underground leak rate model. Our underground leak rate is based on our engineering estimates of the effects of hole diameter and backfill material on the dispersion distance. Our estimates produce reasonable leak rates that exhibit the anticipated sensitivites to changes in key variables, but our estimates could be improved if our leak rate formulas were verified by bench-scale testing.

BIBLIOGRAPHY

Ailor, W.H., *Atmospheric Corrosion*, New York: John Wiley and Sons, 1982.

Aird, R.J., "The Application of Reliability Engineering to Process Plant Maintenance," *The Chemical Engineer*, May 1980, pp. 301-305, 311.

Allocio, M.A., "Hazard Recognition for the Newcomer," *National Safety News*, December 1983, pp. 76-79.

---------, "Guide to Durable Concrete," *Journal of the American Concrete Institute*, Vol. 74, December 1977, pp. 573-609.

American Concrete Institute, *Durability of Concrete*, Publication SP-47, Detroit, 1975.

American Petroleum Institute, "Tank and Piping Leak Survey," Correspondence package from F. B. Killmar, American Petroleum Institute, Washington, D.C., to members of the Operations and Engineering Committee and Underground Leakage Task Force, February 5, 1981.

Andow, P.K., F.P. Lees, and C.P. Murphy, "The Propagation of Faults in Process Plants: A State of the Art Review," *Institution of Chemical Engineering*, Symposium Series No. 58, 1980, pp. 225-243.

Anyakora, S.N., G.T.M. Engel, and T.P. Lees, "Some Data on the Reliability of Instruments in the Chemical Plant Environment," *The Chemical Engineer*, November 1971, pp. 396-402.

Arendt, J.S., W.R. Craig, D.J. Campbell, and D.F. Montague, "Fault Tree Analysis of Refinery Utility Systems," *1983 Proceedings of the Annual Reliability and Maintainability Symposium*, pp. 55-60.

Baldock, P.J., "Accidental Releases of Ammonia: An Analysis of Reported Incidents," *Loss Prevention*, Vol. 13, AIChE, 1980, pp. 35-42.

Bartknecht, W., "Explosion Pressure Relief," *Chemical Engineering Progress*, September 1977, pp. 45-53.

Baumeister, T., E.A. Avallone, and T. Baumeister, III, *Marks' Standard Handbook for Mechanical Engineers*, 8th ed., McGraw-Hill, 1978.

Berenblut, B.J., and H.B. Whitehouse, "A Method for Monitoring Process Plant Based on a Decision Table Analysis," *The Chemical Engineer*, March 1977, pp. 175-181.

Beychok, M.R. "Calculate Tank Losses Easier," *Hydrocarbon Processing*, March 1983, pp. 71-73.

Beyers, C.K., "Failure Analysis: Tool for HPI Loss Prevention," *Hydrocarbon Processing*, August 1980, pp. 155, 159-160.

Preceding page blank

Bjorklund, I., and L.E. Janson, "Swedish Experience of the use of Thermoplastic Pipes for Water and Sewage Transport", Proceedings of the International Conference on Underground Plastic Pipe, New Orleans, La., Mar. 30 -- Apr. 1, 1981, Publ. by ASCE, New York, NY, 1981, pp. 385-400.

Bloch, H.P., "Improve Safety and Reliability of Pumps and Drives," Hydrocarbon Procesing, April 1977, pp. 181-182.

Bocchi, W.J., "Predicting Mechanical Reliability," 1981 Proceedings Annual Reliability and Maintinability Symposium, pp. 33-37.

Bosich, J.F., Corrosion Prevention for Practicing Engineers, Barnes and Noble, Inc.: New York, 1970.

Boyd, D., and J. Leotta, "Prevention: The Usage of the United State's Coast Guard's Pollution Incident Reporting System in Program Management," Proc. of 1976 National Conference on Controls of Hazardous Material Spills, 1976, pp. 94-100.

Bradford, M., and D.G. Darrett, "Avoiding Common Mistakes in Sizing Distillation Safety Valves," Chemical Engineering, July 9, 1984, pp. 78-84.

Bradford, S.A., "Corrosion Failure Expectancy: A Critical Examination," Materials Protection and Performance, 9(7), July 1970, pp. 13-15.

Breipohl, A.M., "A Definition of Probability for Reliability Prediction," Proceedings 1974 Annual Reliability and Maintainability Symposium, pp. 45-47.

Browning, R.L., "Analyzing Industrial Risks," Chemical Engineering, October 20, 1969, pp. 109-114.

---------, "Calculating Loss Exposures," Chemical Engineering, November 17, 1969, pp. 239-244.

---------, "Estimating Loss Probabilities," Chemical Engineering, December 15, 1969, pp. 135-138, 140.

---------, "Finding the Critical Path to Loss," Chemical Engineering, January 26, 1970, pp. 119-124.

---------, "Human Factors in the Fault Tree," Chemical Engineering Progress, June 1976, pp. 72-75.

---------, "Use a Fault Tree to Check Safeguards," Loss Prevention, Volume 12, AIChE, 1979, pp. 20-26.

Buckman, H.D., and N.C. Brady, The Nature and Properties of Soils, 7th ed., MacMillan Co., 1969.

Cherry, K.F., "Sacrificial Component Check Valves Prevent Disasters," Pollution Control, December 1981, pp. 42-43.

Cohen, Y., W.Cocchio, and D. MacKay, "Laboratory Study of Liquid Phase Controlled Volatilization Rates in Presence of Wind Waves," Environmental Science and Technology, Vol. 12, May 1978.

Conover, W.J., Practical Nonparametric Statistics, New York: John Wiley & Sons, 1971.

Constance, J.D., "Control of Explosive or Toxic Air-Gas Mixtures," Chemical Engineering Progress, April 19, 1971, pp. 121-124.

---------, "Pressure Ventilate for Explosion Protection," Chemical Engineering, September 20, 1971, pp. 156-158.

Cooper, C.M., "What to Specify for Corrosion Allowance," Hydrocarbon Processing, May 1972, pp. 123-125.

Craven, A.D., "Fire and Explosion Hazards Associated with the Ignition of Small Scale Unconfined Spillages," Process Industry Hazards: Accidental Release, Assessment, Containment and Control, 1976.

Crocker, B.B., " Preventing Hazardous Pollution During Plant Catastrophes," Chemical Engineering, May 4, 1970, pp. 97-102.

Dartnell, R.C., Jr., and T.A. Ventrone, "Explosion of a Para-Nitro-Meta-Cresol Unit," Chemical Engineering Process, 67(6), pp. 58-61.

Davenport, J.A., "Prevent Vapor Cloud Explosions," Hydrocarbon Processing, March 1977, pp. 205-206, 212-213.

---------, "A Survey of Vapor Cloud Incidents, "Loss Prevention, Vol. 11, AIChE, 1977, pp. 39-48

Davies, R., "Seismic Risk to Liquefied Gas Storage Plant in the United Kingdom," Chemical Engineering Symposium Series No. 71, 1982, pp. 245-300.

Dean, J.A., ed., Lange's Handbook of Chemistry, 12th ed., McGraw-Hill, 1979.

DePaul, D.J., Corrosion and Wear Handbook, New York: McGraw-Hill Book Co., 1957.

Dorsey, J.S., "Using Reinforced Plastics for Process Equipment," Chemical Engineering, September 15, 1975, pp. 104-114.

---------, "Controlling External Underground Corrosion," Chemical Engineering, March 5, 1984, pp. 77-84.

Drowning, R.L., "Analyzing Industrial Risks," Chemical Engineering, October 20, 1969, pp. 109-114.

---------, "Calculating Loss Exposures," Chemical Engineering, November 17, 1969, pp. 239-44.

---------, "Finding the Critical Path to Loss," Chemical Engineering, January 26, 1970, pp. 119-124.

Eagan, H.B. Jr., J.F. Howard, A.C. Smith, and R.E. Diffenbach, "Removal of Hazardous Fluid from the Ground Water in a Congestd Area--A Case History," Proceedings of 1976 National Conference on Controls of Hazardous Material Spills, pp. 373-377.

Entropy Limited (Lincoln Massachusetts), "Review of the W. Rogers Assoc. Report on the Statistical Analysis of Corrosion Failure, Unprotected Underground Steel Tanks," memo from R. Christensen and R. Eilbert, May 4, 1982 (6 pages).

---------, "Decision-Theoretic Assessment of Rogers Model on Underground Tank Leaking," memo from R. Christensen, May 6, 1982 (7 pages).

---------, Estimate of Information Content of PACE Data Base with respect to External Corrosion of Underground Storage Tanks," memo from R. Christensen, June 15, 1982 (7 pages).

Feld, J., Lessons from Failures of Concrete Structures, American Concrete Institute Monograph No. 1, Detroit: American Concrete Institute, and Ames: Iowa State University Press (published jointly), 1964.

Fetter, C.W., Jr., Applied Hydrogeology, Columbus: Charles E. Merrill Publishing Co., 1980.

Ford, H., K.E. Bett, J. Rogan, and H.F. Gardner, "Design Criteria for Pressure Vessels," Chemical Engineering Progress, Vol. 68, No. 11, November 1972, pp. 77-79.

Frankland, P.B., "Relief Valves... What Needs Protection?" Hydrocarbon Processing, April 1978, pp. 189-191.

Gauger, R.H., and N. Holmes, "Black Start Reliability," 1984 Proceeding Annual Reliability and Maintainability, pp. 177-180.

Ghassemi, M., Y. Kar, and F.J. Freeston, "Applicability of Commercialized Wastewater Treatment Techniques to the Treatment of Spill-Impacted Waters," Proceedings of the 1980 National Conference on Control of Hazardous Material Spills, Louisville, Ky., May 1980, pp. 65-71.

Grant, L.H., S.A. Mirza and J.G. MacGregor, "Monte Carlo Study of Strength of Concrete Columns," Journal of the American Concrete Institute, Vol. 75, August 1978, pp. 348-358.

Green, A.E., ed., High Risk Safety Technology, New York: John Wiley and Sons, 1982.

Gustin, R.E., and D.A. Novacek, "Ammonia Storage Vent Accident," Ammonia Plant Safety, Vol. 21, 1979, pp. 80-81.

Hale, C.C., "Refrigerated Ammonia Storage: Design and Practice," Ammonia Plant Safety, Vol. 21, 1979, pp. 61-68.

Hammer, H.S., "Reliability Demonstration Testing Using Failure-Free Trials," Proceedings 1974 Annual Reliability and Maintainabilty, 1974, pp. 201-205.

Hampson, T.R., "Chemical Leak at a Bulk Terminals Tank Farm," Proceedings of 1976 National Conference on Controls of Hazardous Material Spills, pp. 214-218.

Harris, N., and P.D.T. O'Connor, "Reliability Prediction: Improving the Crystal Ball," 1984 Proceedings Annual Reliability and Maintainability Symposium, pp. 108-113.

Hauptmanns, U., and J. Yllera, "Fault-tree Evaluation by Monte Carlo Simulation," Chemical Engineering, January 10, 1983, pp. 91-97.

Hawn, D.E., "Extreme Value Prediction of Maximum Pits on Pipelines," Materials Performance, March 1977, pp. 29-32.

Heitner I., T. Trantmanis, and M. Morrissey, "When gas-filled vessels are exposed to fire . . .," Hydrocarbon Processing, November 1983, pp. 263-268.

Henley, E.J., and H. Kumamoto, Reliability Engineering and Risk Assessment, New Jersey: Prentice-Hall, Inc., 1981.

Holton, G.A., and C.C. Travis, "A Methodology for Predicting Fugitive Emissions for Incinerator Facilities," Environmental Progress, 3(2) May 1984, pp. 116-121.

Holzhauer, R., "Underground Liquid Fuel Storage Tanks," Plant Engineering, April 17, 1980, pp. 98-105.

Hoyle, W.C., and G.L. Melvin, "A Toxic Substance Leak in Retrospect: Prevention and Response," Proceedings of 1976 National Conference on Controls of Hazardous Material Spills, pp. 187-191.

Howard, W.B., "Hazards with Flammable Mixtures," Chemical Engineering Progress, Vol. 66(9), September 1970, pp. 59-62.

"How to Set Up an Emergency Response System," National Safety News, November 1983, p. 37.

Hulme, B.L., and R.B. Worrell, "Algebraic Approximation of Event Tree Sequences," 1983 Proceedings of the Annual Reliability and Maintainability Symposium, pp. 61-62.

Hwang, S.T. Toxic Emissions from Land Disposal Facilities. Environmental Progress, 1(1) February 1982.

ICF, Inc., "RCRA Risk/Cost Policy Model Project Phase 2 Report," for U.S. Environmental Protection Agency, Office of Solid Waste, June 15, 1982.

Illinois Legislative Investigating Commission, Landfilling of Special and Hazardous Waste: A Report to the Illinois General Assembly, August 1981.

Ishikawa, Y., T. Ozaki, N. Hosaka, and O. Nishida, "Corrosion Life Prediction of Machine Components by Extreme Value Statistical Analysis," Fushoku Boshoku Bumon Iinkai Shiryo, 20(3), 1981, pp. 73-77 (Japan).

---------, "Statistical Properties of Crevice Corrosion Behavior," Tetsu to Hagane, Vol. 68, 1982, pp. A203-A206 (Japan).

James Jr., R., "Maintenance of Rotating Equipment: Pump Maintenance," Chemical Engineering Progress, February 1976, pp. 35-40.

Jarvis, H.C. "Butadiene Explosion at Texas City--1," Chemical Engineering Progress, 67(6), June 1971, pp. 41-44.

Jennings, A.L., and C.R.Gentry, "The Use of Spill Potential in the Designation of Hazardous Substances," Control of Hazardous Material Spills, Proceedings of 1976 National Conference on Controls of Hazardous Material, pp. 44-48.

Johnson, D.M., "The Billion Gallon Tank Farm," Chemical Engineering Progress, 65(4), April 1969, pp. 41-43.

Johnston, G.O., "Probabilistic Fracture Mechanics (PFM)," in T.R. Moss, ed., Mechanical Reliability, Science & Technology Press, Ltd., 1980, pp. 8-34.

Joller, J.M., "Constructing Fault-Trees by Stepwise Refinements," IEEE Transactions on Reliability, Vol. R-31, No. 4, October 1982, pp. 333-338.

Jones, J.R., "The Selection of Pumps for Filtration Duties", Filtration and Separation, March/April, 1980, pp. 120-128.

JRB Associates, "Failure Incident Analysis: Evaluation of Storage of Failure Points," draft prepared for U.S. Environmental Protection Agency, Office of Solid Waste, March 1982.

Kanda, K., "Computerization of System/Product Fault Trees," Annals of Assurance Sciences, 8th Reliability and Maintainability Conference, 1969, pp. 325-333.

Kasouf, G. and D.A. McGoye, "R/M Design for Long Term Dormant Storage," 1984 Proceedings Annual Relability and Maintainability Symposium, pp. 168-176.

Kern, R., "Pressure-Relief Valves for Process Plants," Chemical Engineering, February 28, 1977, pp. 187-194.

Khandelwal, U.C., "For Cradle-to-Grave Protection Assign Hazardous Materials Duty," National Safety News, July 1983, pp. 65-68.

Kiang, Y.H. and A.A. Metry, Hazardous Waste Processing Technology, Ann Arbor: Ann Arbor Science, 1982.

Kirby, G.N., "How to Specify Fiberglass Reinforced-Plastics Equipment, "Chemical Engineering, June 5, 1978, pp. 133-138.

Klee, A.J., The Mouse Manual, U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, June, 1981.

Kletz, T.A., "Case Histories on Loss Prevention," Loss Prevention, Vol. 8, AIChE, 1974, pp. 126-130.

---------, "Preventing Catastrophic Accidents," Chemical Engineering, April 12, 1976, pp. 124-128.

---------, "Protect Pressure Vessels from Fire," Hydrocarbon Processing, August 1977, pp. 98-102.

---------," Practical Applications of Hazard Analysis," Chemical Engineering Progress, October 1978, pp. 47-53.

---------, "Minimize your Product Spillage," Hydrocarbon Processing, March 1982, pp. 207-208, 210.

Koeppe, C.E., and G.C. DeLong, Weather and Climate, New York: McGraw-Hill Book Co., 1958.

Kolodner, N.J., "Use a Fault-Tree Approach, "Hydrocarbon Processing, September 1977, pp. 303-304, 306, 308.

Kramer, W.H., "Ground-Water Pollution from Gasoline," GWMR, Spring 1982, pp. 18-22.

Kunii, D., and O. Levenspiel, Fluidization Engineering, New York: John Wiley and Sons, Inc., 1969.

Lafornara, J.P. and J.S. Dorrler, "The Environmental Response Team," Proceedings of the 1980 National Conference on Control of Hazardous Material Spills, Louisville, Ky., May 1980, pp. 476-481.

Lambert, R.G., "Low Cycle Fatigue Reliability Expressions," 1982 Proceeding Annual Reliability and Maintainability Symposium, pp. 47-50.

Langley, G.J., S.M. Dennis, J.F. Ward, and L.P. Provost, "Analysis of SOCMI VOC Fugitive Emission Data," EPA-600/S2-81-111, U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, EPA-600 S2-81-111, September 1981.

Lapp, S.A., and G.J. Powers, "Computer-Aided Synthesis of Fault Trees," IEEE Transactions on Reliability, April 1977, pp. 2-15.

Lawrence, W.E., and E.E. Johnson, "Design for Limiting Explosion Damage," Chemical Engineering, January 7, 1984, pp. 96-104.

Lawley, H.G., "Operability Studies and Hazard Analysis," Chemical Engineering Progress, 70(4), April 1974, pp. 45-56.

---------, "Size up Plant Hazards This Way," Hydrocarbon Processing, April 1976, pp. 247-248, 250, 252, 256, 258, 260-61.

Lewis II, E.C., "Mud Pump Failure Analysis, Part 4 - Extrusion, The Primary Cause of Piston Failure," Petroleum Engineer, October 1981, pp. 130-144.

Lindorff, D.E., and K. Cartwright, "Ground-Water Contamination: Problems and Remedial Actions," Illinois Geological Survey, Environmental Geology Notes, No. 81, 1977.

Mackay, D., S. Paterson, and S. Nadeau, "Calculation of the Evaporation Rate of Volatile Liquids," Proceedings of the 1980 National Conference on Control of Hazardous Material Spills, Louisville, Ky., May 1980, pp. 361-368.

Mann L., Jr., and H. H. Bostock, "Short-range Maintenance Planning/Scheduling Using Network Analysis," Hydrocarbon Processing, March 1983, pp. 97-101.

Martinez, E.C., "Storage Reliability with Periodic Test," 1984 Proceedings Annual Reliability and Maintainability Syposium, pp. 181-185.

McIntyre, D.R., "How to Prevent Stress-Corrosion Cracking in Stainless Steels--I," Chemical Engineering, April 7, 1980, pp. 107-112.

---------, "How to Prevent Stress-Corrosion Cracking in Stainless Steels--II," Chemical Engineering, May 5, 1980, pp. 131-132, 134, 136.

---------, "Evaluating the Cost of Corrosion-Control Methods," Chemical Engineering, April 5, 1982, pp. 127-132.

McKay, F.F., G.R. Worrell, B.C. Thornton, and H.L. Lewis, "If an ethylene pipe line ruptures . . .", Hydrocarbon Processing, 56(11), 1977, pp. 487.

McIntyre, D.R., "How to Prevent Stress-Corrosion Cracking in Stainless Steels-II," Chemical Engineering, 5 May 1980, pp. 131-132, 134, 136.

Miller, M.J., "Reliability of Fire Protection Systems," Loss Prevention, Vol. 8, AIChE, 1974, pp. 85-90.

Moore, C.G., "Automated System Provides Corrosion Data Before Disaster," Pollution Engineering, June 1984, pp. 42-43.

National Association of Corrosion Engineers, Technical Practices Committee, "Recommended Practice: Control of Internal Corrosion in Steel Pipelines and Piping Systems," NACE Standard RP-01-75, 1975.

---------, "Recommended Practice: Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems," NACE Standard RP-02-85, April 10, 1985.

---------, and American Petroleum Institute, Corrosion of Oil and Gas-Well Equipment (1958).

National Research Council Canada, "A Case Study of Industrial Chemicals--Polychlorinated Biphenyls and Chlorinated Benzenes," NRCC No. 17586, 1980.

New York State Department of Environmental Conservation, Siting Manual for Storing Hazardous Substances: A Practical Guide for Local Officials, Albany, 1982.

---------, Administrative and Legal Options for Storing Hazardous Substances: A Guide for Local Officials, Albany, 1984.

---------, Recommended Practices for Underground Storage of Petroleum, Albany, 1985.

---------, Technology for the Storage of Hazardous Liquids: A State-of-the Art Review, Albany, 1985.

"News in Brief: Research and Technology," Hazardous Material Intelligence Report, August 26, 1983, pp. 3-4, 8.

Nowak, A.S., "Effect of Human Error on Structural Safety," Journal of the American Concrete Institute, Vol. 76, September 1979, pp. 959-972.

Owens, M., R.W. Edwards, and J.W. Gibbs, "Some Reaeration Studies in Streams," International Journal of Air and Water Pollution, Vol. 8, 1964.

Ozog, H., "Hazard Identification, Analysis, and Control," Chemical Engineering, February 18, 1985, pp. 161-170.

Petak, W.J., and A.A. Atkisson, National Hazard Risk Assessment and Public Policy: Anticipating the Unexpected, New York: Springer-Verlag (1982).

Peters, M.S., and K.D. Timmerhaus, Plant Design and Economics for Chemical Engineers, 3rd ed., McGraw-Hill, 1980.

Perry, R.H., and C.H. Chilton, eds. Chemical Engineers Handbook, 5th ed., McGraw-Hill, 1973.

Petersen, H.J.S., and P. Haastrup, "Fault-Tree Evaluation Shows Importance of Testing Instruments and Controls," Chemical Engineering, November 26, 1984, pp. 85-87.

Petroleum Association for Conservation of the Canadian Environment, "Underground Tank Systems. Review of State of the Art and Guidelines," PACE Report No. 82-3, Ottawa (1983).

Pope-Reid Associates, "Assessment of the Technical, Environmental and Safety Aspects of Storage of Hazardous Waste in Underground Tanks," Volume I, Draft Report, Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, August 25, 1983.

---------, "Liner Location Risk Analysis Model," Draft Report, Appendix A--Failure Analysis," St. Paul, MN, 1984.

---------, The Analysis of Component Failures of Hazardous Waste Storage and Treatment Systems: Annotated Bibliography (Draft, July 1984)

Portland Cement Association (Minneapolis, Minnesota), "Concrete Systems for Manure Handling," Bulletin #NCR-A283, undated.

Portland Cement Association (Skokie, Illinois), "Circular Concrete Tanks Without Prestressing," Concrete Information, BUlletin #IS072.01D, undated.

---------, "Rectangular Concrete Tanks," Concrete Information, Bulletin #IS003.03D, Revised 1981.

---------, "Underground Concrete Tanks," Concrete Information, Bulletin #IS071.03D, undated.

---------, Design and Control of Concrete Mixtures, Twelfth Edition, 1979.

---------, Building Movements and Joints, 1982.

Powers, G.J., and S.A. Lapp, "Computer-Aided Fault Tree Synthesis," Chemical Engineering Progress, April 1965, pp. 89-93.

Powers, G.J., and F.C. Tompkins, Jr., "Fault Tree Synthesis for Chemical Processes," AIChE Journal, 20(2), March 1976, pp. 376-387.

Preddy, D.L., "Guidelines for Safety and Loss Prevention," Chemical Engineering, April 21, 1969, pp. 94-108.

Prestigiacomo, N.M., and J.H. Stokes, "Developing New API-650 Appendix H," Hydrocarbon Processing, May 1978, pp. 170-171.

Priestly, M.J.N. "Ambient Thermal Stresses in Circular Prestressed Concrete Tanks," Journal of the American Concrete Institute, Vol. 73, October 1976, pp. 553-560.

Prugh, R.W., "Application of Fault Tree Analysis," Loss Prevention, Volume 14, AIChE, 1981, pp. 1-10.

Roberts, R.J., J.A. Cherry, and F.W. Schwartz, "A Case Study of a Chemical Spill: Polychlorinated Biphenyls (PCB's) 1. History, Distribution, and Surface Translocation," Water Resources Research, June 1982, pp. 525-534.

---------, "A Case Study of a Chemical Spill: Polychlorinated Biphenyls (PCB's) 2. Hydrological Conditions and Contaminant Migration," Water Resources Research, June 1982, pp. 535-545.

Roebuck, A.H., and G.H. Brevoort, "Coating Work Costs and Estimating," Materials Performance, 22(1), January 1983, pp. 43-457.

"Rogers Finds Leaks by Using Statistics," Petroleum Marketer, November/December 1982, pp. 17-20.

Rooney, J.P., "Predict Reliability of Instrumentation," Hydrocarbon Processing, January 1983, pp. 89-92.

Rossum, J.R., "Prediction of Pitting Rates in Ferrous Metals from Soil Parameters," Jour. AWWA, June 1969, pp. 305-310.

Sangerhausen, C.R., "Reduce Seal Failures in Tight Hydrocarbon Service, Part 1--Design Considerations," Hydrocarbon Processing, January 1981, pp. 111-116.

---------, "Reduce Seal Failures in Tight Hydrocarbon Service, Part 2--Commissioning Procedures," Hydrocarbon Processing, March 1981, pp. 119-122.

Sax, N., and I. Van Nostrand, Dangerous Properties of Industrial Materials, 4th edition, Reinhold Company, 1975, Appendix 2, pp. 268-269.

Schillmoller, C.M., and H.J. Althoff, "How to Avoid Failures of Stainless Steels," Chemical Engineering, May 28, 1984, pp. 119-120, 122.

Schultz, D.W., and V.B. Parr, "Project Summary: Evaluation and Documentation of Mechanical Reliability of Conventional Wastewater Treatment Plant Components," United States Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, EPA-600/S2-82-044, August, 1982.

Schwerdtfeger, W.J., "Laboratory Measurement of the Corrosion of Ferrous Metals in Soils," Journal of Research of the National Bureau of Standards, 50(6), June 1953, pp. 329-336.

SCS Engineers, "Final Report: Assessment of the Technical, Environmental and Safety Aspects of Storage of Hazardous Waste in Underground Tanks," Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, February 1984.

---------, "Estimated Cost of Compliance with RCRA Regulations for Underground Tank Storage Facilities," Volume 1, Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, March 1984.

Sheppard, W.L., Jr., "Failure Analysis of Chemically Resistant Monolithic Surfacing," Chemical Engineering, July 23, 1984, pp. 124-125.

Shields, E., and W.J. Dessert, "Learning a Lesson from a Sulfuric Acid Tank Failure," Pollution Engineering, December 1981, pp. 39-40.

Siegel, R.D., "Controls Developing for Fugitive Emissions," Hydrocarbon Processing, October 1981, pp. 105-108.

Sobotka and Company, "Developing and Assessing Regulatory Options for Testing, Monitoring, Recordkeeping and Reporting in Response to Leaking Underground Storage Tanks," Draft Final Report, for the U.S. Environmental Protection Agency, Office of Toxic Substances, June 1984.

Sonti, R.S., "Practical Design and Operation of Vapor-Depressuring Systems," Chemical Engineering, January 23, 1984, pp. 66-69.

Southwest Research Institute, "Evaluation and Documentation of Mechanical Reliability of Conventional Wastewater Treatment Plant Components," EPA 600/2-82-044, U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, 1982.

Sowers, G.B., and G.F. Sowers, Introductory Soil Mechanics and Foundations, 3rd ed., New York: MacMillan, 1970.

Stephens, T.J.R., and C.B. Livingston, "Explosion of a Chlorine Distillate Receiver," *Chemical Engineering Progress*, 69(4), April 1973, pp. 45-47.

"STI-P3 Tanks," *Tulsa Letter*, November 1, 1983, p. 3.

Tepfers, R. and T. Kutti, "Fatigue Strength of Plain, Ordinary and Lightweight Concrete," *Journal of the American Concrete Institute*, Vol. 76, May 1979, pp. 635-652.

Thibault, G.T., and W.N. Elliott, "Biological Detoxification of Hazardous Organic Chemical Spills," in *Proceedings of the 1980 National Conference on Control of Hazardous Material Spills*, Louisville, Ky., May 1980, pp. 398-402.

Thibodeaux, L.J., *Chemodynamics*, New York: John Wiley & Sons, 1979.

Thibodeaux, L.J., D.G. Parker, H.H. Heck, and R. Dickerson, "Quantifying Organic Emission Rates from Surface Impoundments with Micrometeorological and Concentration Profile Measurements," presented at the annual meeting of American Institute of Chemical Engineers, New Orleans, LA, November 8-12, 1981.

Tomsky, J., "Analysis of Variance of Reliabilities," *1983 Proceedings of the Annual Reliability and Maintainability Symposium*, pp. 63-70.

Tsujikawa, S., H. Cha, K. Hisamatsu, K, "Stochastic Theory Evaluation of the Critical Potential and Onset Time of Crevice Corrosion in Stainless Steel," *Tetsu to Hagane*, Vol. 68, 1982, pp. A207-A210 (Japan).

"TR-9 Circular Concrete Manure Tanks," *Technical Resource*, ISBN 0-89373-059-9, November 1983.

Transportation Research Board, "Durability of Drainage Pipe," *National Cooperative Highway Research Program Synthesis of Highway Practice*, 1978, pp. 24-30.

"Underground Unprotected Steel Tank Study: Statistical Analysis of Corrosion Failures," (undated, author unknown), memo included in correspondence package from B. Tam, U.S. Environmental Protection Agency, Office of Solid Waste, Economic Analysis Branch, to C. Lough, Project Director, Pope-Reid Associates, Inc., May 14, 1984.

United States Coast Guard, *Deep Water Port Inspection Methods and Procedures*. Report #CG-O-31-78 (1978).

United States Department of the Interior, Water and Power Resources Service, *Concrete Manual, A Water Resources Technical Publication*, 8th Ed., 1981.

United States Environmental Protection Agency, *Case Studies 1-23: Remedial Response at Hazardous Waste Sites*, EPA-540/2-84-0026, March 1984.

---------, *Control of Volatile Organic Emissions from Petroleum Liquid Storage in External Floating Roof Tanks*, EPA-450/2-78-047, OAQPS No. 1.2-116, December 1978.

---------, *Proceedings Fourth Symposioum on Fugitive Emissions: Measurement and Control*, New Orleans, May 1980, EPA-600/9-80-041, December 1980.

---------, *Summary Report: Remedial Response at Hazardous Waste Sites*, EPA-540/2-84-002a, March 1984.

---------, and Hazardous Materials Control Research Institute, *Management of Uncontrolled Hazardous Waste Sites*, Proceedings of a national conference, Washington, D.C., October 28-30, 1981.

United States Nuclear Regulatory Commission, *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants*, (usually cited as WASH-1400), 1975, Appendices III and IV.

Vervalin, C.H., "Fire and Safety Information: A Description of Key Resources," *Hydrocarbon Processing*, April 1972, pp. 163-165.

---------, "Learn from HPI Plant Fires," *Hydrocarbon Processing*, December 1972, pp. 49-53.

---------, "HPI Loss-Incident Case Histories," *Hydrocarbon Processing*, February 1978, pp. 183-184, 189-190, 195-196, 198-200.

---------, "How to Prevent Stress-Corrosion in Stainless Steels-I," *Chemical Engineering*, April 7, 1980, pp. 107-108, 110, 112.

---------, "Define Loss Prevention Problems and Remedies," *Hydrocarbon Processing*, December 1983, pp. 111-112, 114, 117.

Vesely, W.E., "Reliability Quantification Techniques Used in the Rasmussen Study," *Reliability and Fault Tree Analysis: Theoretical Aspects of System Reliability and Safety Assessment*, Edited by R.E. Barlow, J.B. Fussell, and N.D. Singpurwalla, Philadelphia: Society for Industrial and Applied Mathematics, 1975., pp. 775-803.

---------, "The Facade of Probabilistic Risk Analysis: Sophisticated Computation Does Not Necessarily Imply Credibility," *1983 Proceeding Annual Reliability and Maintainability Symposium*, pp. 49-51.

Wafelman, H.R., and H. Buhrmann, "Maintain Safer Tank Storage," *Hydrocarbon Processing*, January 1977, pp. 229-230, 232, 234-235.

Wallace, A.E., and W.P. Webb, "Cut Vessel Costs with Realistic Corrosion Allowances," *Chemical Engineering*, August 24, 1981, pp. 123-126.

Warner, R.F., and A.P. Kabaila, "Monte Carlo Study of Structural Safety," *Proceedings ASCE*, Vol. 94, December 1968, pp. 2847-2859.

Warren Rogers Associates, Inc., "National and Regional Profiles of Underground Storage Tank Characteristics," Report Submitted to the U.S. Environmental Protection Agency in or about 1984, included in correspondence package from D. Samuelson, Sobotka & Co., to R. Lovett, Pope-Reid Associates, received July 25, 1985.

---------, "Prediction of Leaks in Unprotected Steel Storage Tanks," included in correspondence package from B. Tam, U.S. Environmental Protection Agency, Office of Solid Waste, Economic Analysis Branch, to. C. Lough, Project Director, Pope-Reid Associates, Inc., received May 14, 1984.

---------, "Tank Integrity Program" (undated memo), included in correspondence package from B. Tam, U.S. Environmental Protection Agency, Office of Solid Waste, Economic Analysis Branch, to C. Lough, Project Director, Pope-Reid Associates, Inc., May 14, 1984.

Washa, G.W. and K.F. Wendt, "Fifty Year Properties of Concrete," Journal of the American Concrete Institute, Vol. 71, January 1975, pp. 20-28.

Wells, J.E., and D.A. Lappa, "Probabilistic Culling in Fault Free Evaluation," 1983 Proceedings Annual Reliability and Maintainability Symposium, pp. 52-54.

White, Frank M., Fluid Mechanics, McGraw-Hill, 1979.

Whittaker, K.T., and R. Goltz, "Cost Effective Management of an Abandoned Hazardous Waste Site by a Staged Clean-up Approach," Management of Uncontrolled Hazardous Waste Sites, 1982, p. 262.

Williams, B.E., "The Probability of Failure for Piping Systems," Failure Prevention and Reliability, 1981 Proceedings of the Design Engineering Technical Conference, Hartford, CT, September 20-23, 1981, Published by ASME, New York, NY, pp. 147-150.

Wirth, G.F., "Preventing and Dealing With In-Plant Hazardous Spills," Chemical Engineering, August 18, 1975, pp. 82-96.

Woods, H., Durability of Concrete Construction, American Concrete Institute Monograph, No. 4, Detroit: American Concrete Institute, and Ames: Iowa State University Press (published jointly), 1968.

Woods, P.H., and D.E. Webster, "Underground Storage Tanks: Problems, Technology, and Trends," Pollution Engineering, July 1984, pp. 30-40.

Worrell, R.B., and B.L. Hulme, "Algebraic Approximation of Event Tree Sequences," 1983 Proceedings of the Annual Reliability and Maintainability Symposium, pp. 61-62.

Yedidiah, S., "Diagnosing Problems of Centrifugal Pumps--Part I," Chemical Engineering, October 24, 1977, pp. 124-128.

---------, "Diagnosing Problems of Centrifugal Pumps--Part II," Chemical Engineering, November 21, 1977, pp. 193-199.

---------, "Diagnosing Problems of Centrifugal Pumps--Part III," Chemical Engineering, December 5, 1977, pp. 141-143.

DRAFT REPORT

HAZARDOUS WASTE
TANK FAILURE MODEL:
DESCRIPTION OF METHODOLOGY
APPENDIX A, B, C

Prepared for:

U.S. Environmental Protection Agency
Office of Solid Waste
Economic Analysis Branch
January 13, 1986

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APPENDIX A

PROBABILITY AND RELEASE VOLUME CALCULATIONS

A.0 INTRODUCTION

This appendix consists of two parts: the derivation of formulas used throughout the failure analysis, and the documentation of the failure probabilities and leak rates used for the individual failure events. The general derivations are presented on pages A-2 through A-11. The individual failure events are discussed in the remainder of this Appendix.

A.1 GENERAL DERIVATIONS

The following computations were common to many of the failure events:

- Calculation of release rates from underground leaks (fluid bed model);
- Calculation of release rates into an air environment (Bernoulli flow);
- Conversion from hydraulic head to pressure;
- Computation of fluid velocity in pipes;
- Determination of pressure of flowing liquid in pipes; and
- Calculation of fill/discharge times.

These calculations are described in the following pages.

A.1.1. Underground Releases (for leaks that are impeded by soil or backfill)

EQUATIONS:

- We calculated underground leak rates using the Ergun equation for the pressure drop in beds of mixed particles (Source: Fluidization Engineering, Daizo Kunii and Octave Levenspiel, p. 70 (1969)). This equation is:

$$\frac{\Delta P}{L} g_c = 150\left(\frac{(1-E_m)^2}{E_m^3}\right)\left(\frac{\mu u_o}{(\phi_s d_p)^2}\right) + \left(\frac{1.75\ (1-E_m)}{E_m^3}\right)\left(\frac{\rho u_o^2}{\phi_s d_p}\right)$$

where

P = the pressure drop across the bed

E_m = the void fraction for the particles

μ = viscosity

u_o = velocity of flow

ϕs = sphericity of the particles

ρ = density of fluid

d_p = average particle size

g_c = 1 in metric units

L = the dispersion length

- This is a quadratic equation in u_o. Thus,

$$u_o = \frac{-B + (B^2 - 4AC)^{.5}}{2A}$$

where $A = \left(\frac{1.75(1-E_m)}{E_m^3}\right)\left(\frac{\rho}{\phi_s d_p}\right)$

$$B = \frac{150(1-E_m)^2}{E_m^3\ (\ {}_s d_p)^2}$$

$$C = \left(\frac{-\ \Delta P}{L}\right) g_c$$

- The leak rate is simply

$$dQ/dt = u_0A$$

- L for fluid beds is approximately 4 to 5 bed diameters. (Source: R. H. Perry and C. H. Chilton, Chemical Engineers' Handbook, 5th Ed (1973), pp. 5-49). The underground leaks studied in this model, however, involve conical dispersion patterns, rather than the cylindrical fluid beds considered by Perry and Chilton. In addition, L will also vary with the dispersion characteristics of the surrounding backfill. After extensive analysis and sample calculations, we have chosen the following dispersion lengths:

	Backfill Material			
	Clay	Silt	Sand	Gravel
Circular holes				
(usual value)	2d	7.5d	20d	100d
(maximum permissible)	2 cm	7.5 cm	20 cm	100 cm
Cracks				
(usual value)	4 w	20 w	40 w	100 w
(maximum permissible)	4 cm	20 cm	40 cm	100 cm

where:

d is the hole diameter, and
w is the crack width

- Additional parameters are as follows:

	Backfill Material			
	Clay	Silt	Sand	Gravel
void fraction	0.95	0.75	0.53	0.50
particle size (mm)	0.002	0.064	0.25	9.4
sphericity	0.075	0.34	0.65	0.70

USER INPUTS:

- Pressure
- Area of hole
- Density of liquid
- Viscosity of liquid
- Soil characteristics
- Type of hole (circular or crack)
- Diameter or width of hole

A.1.2. Bernoulli Flow (into an air environment)

EQUATIONS:

- This calculation applies to leaks that are unimpeded by soil resistance.
- The loss rate can be calculated by a simple application of Bernoulli's equation for a sharp-edged orifice.
- $dQ/dt = .6A\ (2gz)^{.5}$

  where

  dQ/dt = leak rate

  A = area of hole

  g = acceleration due to gravity

  z = height of liquid

USER INPUTS:

- Hydraulic head
- Area of hole

COMMENTS:

- The flow through small holes under relatively low pressure is turbulent, as can be verified by calculating a typical Reynold's number. The Reynolds number for loss through a (1/32)" hole for methylene chloride under 2 feet of head is 7500. This is in the upper end of the transition zone between turbulent and laminar flow. Use of Poiseville's Equation for laminar flow gives a considerably higher flow rate, so turbulent flow will be assumed.

A.1.3. Conversion from hydraulic head to pressure

EQUATIONS:

- Some equations in this Appendix use ΔP (pressure drop). Others call for z (hydraulic head). These two quantities are related by the following formula:

$$\Delta P = \rho(g/g_c)z$$

where

ρ = density of fluid

g = acceleration due to gravity

g_c = a conversion factor which is 1 in metric units and 32.17 in English units

USER INPUTS:

- Hydraulic head or pressure drop
- Density of fluid

A.1.4. Fluid velocity in pipes

EQUATIONS:

- For flowing fluid in a pipe, the following energy balance equation applies (Source: M. S. Peters and K. D. Timmerhaus, Plant Design and Economics for Chemical Engineers, 3rd Ed (1980) pp. 509-515):

$$\frac{P_1}{\rho\frac{g}{g_c}} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho\frac{g}{g_c}} + \frac{V_2^2}{2g} + z_2 + h_s + h_f$$

where

P_1 = inlet pressure

ρ = density

g = acceleration of gravity

g_c = a conversion factor (1 in metric units, 32.17 in English units)

V_1 = inlet velocity

z_1 = inlet elevation above arbitrary base

P_2 = outlet pressure

V_2 = outlet velocity

z_2 = outlet elevation

h_s = hydraulic head added by the pump

h_f = frictional losses (measured as loss of hydraulic head)

- F is composed of 3 parts: losses at entrance to pipe, losses along the pipe, losses at pipe exit.
- The following frictional loss equations apply to these losses (Source: Peters and Timmerhaus)

sudden enlargement

$$F_e = \frac{(V_1-V_2)^2}{2ga} \qquad a = 1 \text{ (turbulent flow)}$$

sudden contraction

$$F_c = \frac{K_c V_2{}^2}{2ag}$$

$a = 1$
$K_c = .05$ for large diameter-changes

pipes and pipe elbows

$$F = \frac{2fv^2(L_e + L)}{gD}$$

f = friction factor = 5×10^{-3} for turbulent flow

L = length of straight pipe

L_e = effective length of elbows

D = diameter of pipe

- For systems open to the atmosphere $P_1 = P_2 = 1$ atm
- For large inlet tanks, $V_1 = 0$
- Set $z_1 = 0$
- Then

$$V_2{}^2 = 2g\ (-z_2 - h_s - h_f)$$

$V_2{}^2$ also appears in h_f, so

$$V_2{}^2 = -(z_2 + h^s)\left(\frac{1}{2g} - \frac{1}{2g} + \frac{1}{4g} + \frac{10^{-2}(L_e + L)}{gD}\right)^{-1}$$

$$= -(z_2 + h_s)\left(\frac{1}{4g} + \frac{10^{-2}(L_e + L)}{gD}\right)^{-1}$$

A.1.5. Pressure of flowing liquid in pipes

EQUATIONS:

- Pressure in a pipe is given by solving the energy balance equation in Section A.1.4 for P_2. Hence:

$$P_2 = P_1 - \left(\rho \frac{g}{g_c}\right)\left(\frac{V_2^2}{2g} + z_2 + h_s + h_f\right)$$

where $V = V_2$ = velocity of flow

- The pressure difference between the pipe interior and the pipe exterior is given by $\Delta P = P_2 - P_1$. Thus:

$$\Delta P = -\left(\frac{g\rho}{g_c}\right)\left(\frac{V_2^2}{2g} + z_2 + h_s + h_f\right)$$

- At the midpoint of the pipe, the friction losses include only losses from the inlet and half of the effective pipe length. Hence, at the midpoint of the pipe:

$$\begin{aligned} h_f &= F_c + \frac{1}{2}F \\ &= \frac{.05V^2}{2g} + \frac{5 \times 10^{-3}\ V^2(L_e + L)}{gD} \end{aligned}$$

- Thus, substituting this equation in the preceding equation gives:

$$\Delta P = \left(\frac{-\rho}{g_c}\right)\left(\frac{V^2}{2} + \frac{.05V^2}{2} + \frac{5 \times 10^{-3}\ (L_e + L)V^2}{D} + gz_2 + gh_s\right)$$

$$\Delta P = \left(\frac{-\rho}{g_c}\right)\left(.525V^2 + \frac{5 \times 10^{-3}\ (L_e + L)V^2}{D} + gz_2 + gh_s\right)$$

A.1.6. Fill/discharge time

EQUATIONS:

- The length of time necessary for tank filling or discharge can be calculated from the fluid velocity in the pipe, the pipe diameter, and the volume to be transferred:

$$T = Q/\pi r^2 v$$

where

Q = transfer volume
r = inside radius of pipe
v = velocity of flow

USER INPUTS:

- Transfer volume
- Velocity of flow (from Section A.1.4)
- Pipe diameter (interior)

A.2 FAILURE DATA SHEETS

The following data sheets discuss the probabilities and release volumes for individual fault tree events.

The events discussed in these data sheets generally represent individual fault tree events, but there is not always a one-to-one correspondence. When it facilitates discussion, we have sometimes combined similar events. In addition, we have occasionally divided our discussion of single fault-tree events in order to focus more clearly on the differences between various tank designs or operating conditions. These changes in the fault tree event classifications have been clearly labeled.

For these reasons, it is not appropriate to read one data sheet without also becoming familiar with the data sheets for similar events. Important caveats may apply to a whole series of events, but in order to focus on the differences among related events, all similarities are not necessarily re-stated. Liberal cross-references have been supplied, but they are not a substitute for a careful reading of the related data sheets.

The labels for the events described in these data sheets may be confusing to the first-time reader. Therefore, the following guide may be useful:

Label Prefix	Category of Event Depicted
Txxxx	Tank defects (corrosion, rupture, etc.)
B1x	Piping, flanges, and gaskets
B2x - B6X	Secondary-containment devices
A1111x	Spills during discharge
A21x	Release routes for overflows (corroded vent pipe, corroded flanges, open-topped tank, etc.)
ANUCAT (I, x)	Catastrophic events (flood, fire, etc.)
LIFDEF (I, x)	Lifetime defects (improper installation, damage during installation, etc.)

xxxxxx	Miscellaneous events (including overfill, operator error, alarm failure, level gauge failure, etc.) These are listed in alphabetical order.

It may also be useful to summarize a few items of commonly-occurring notation:

Notation	Explanation
p	Binomial probability.
N(x,y)	Normal distribution with mean of x, standard deviation of y.
pN(x,y)	Conditional normal distribution. p is the binomial probability that failure occurs; N(x,y) is the distribution of times to failure given that failure does occur.
FNU(x,y)	A uniform distribution between x and y.
Maximum = y	Unless a minimum is also specified, this means FNU(0,y).
B(a,b,c)	Beta distribution with minimum value a, mode b, and maximum c.

These explanations should make the event sheets more accessible to the general reader.

LABEL: T1121

FAILURE: Localized exterior corrosion

SOURCES: Petroleum Association for Conservation of the Canadian Environment, "Underground Tank Systems: Review of State of the Art and Guidelines," PACE Report No. 82-3, Ottawa (1983).

CALCULATIONS:

- The PACE data are presented and analyzed in Appendix C.
- The results of that analysis are cumulative time-to-failure distributions for each of 3 categories of Soil Aggressiveness Values (SAV's). (SAV's are discussed in Appendix C).

Cumulative Probability of Failure

Tank Age	Low SAV (0-6)	Medium SAV (7-12)	High SAV (< 13)
4	0	0	0
9	0	11.1	26.7
14	6.3	29.1	49.9
19	24.0	54.0	76.5
24	48.3	67.3	79.9
30[1]	69.9	76.6[2]	83.3

[1] This age has been chosen as representative of the ≥ 25 bracket.

[2] A probability for this category could not be calculated from the raw data. In order to complete the table, this number was obtained by averaging 69.9 and 83.6. It appears to be a reasonable value.

PROBABILITY DISTRIBUTION: Empirical

PROBABILITY: See above table.

DATE OF INITIAL RELEASE:

- SAV must first be calculated as shown in Appendix C. This will require the following inputs:
  - Soil resistivity (ohm-cm)
  - Soil pH
  - Soil moisture

  - Presence or absence of sulfides
  - Differential characteristics

- The failure date may now be sampled from the probability table.

- A corrosion rate may be obtained by dividing the resulting failure date by the average tank wall thickness for the tanks in the PACE survey. This thickness is assumed to be .25 inches.

- The date of failure will be the date at which the sum of accumulated local external corrosion plus general internal corrosion reaches the initial wall thickness of the tank in question. (General internal corrosion is calculated under event T1125). General exterior corrosion does not enter into this analysis, for we assume that it is already included in the corrosion rate for localized exterior corrosion. In addition, localized interior corrosion is not included in this analysis, for it is unlikely that localized internal and external corrosion will occur at the same point on the tank wall. Thus, it is unlikely that pits from these two causes will "meet in the middle."

MATERIALS AND CONFIGURATION VARIATIONS:

- The PACE-derived probability distribution is assumed to apply only to unprotected steel tanks.

- Material changes, use of cathodic protection, and use of coatings will alter corrosion probabilities and hence dates of failure. These effects are summarized in the following table:

Tank design	Effect on probability of failure
Carbon steel (underground, unprotected)	PACE baseline
Carbon steel (underground, coated)	Delays onset of corrosion by N(7,3) years, then corrosion becomes a certainty. Time-to-failure distribution is given below.
Carbon steel (above-ground, unprotected)	Corrodes like underground tank with 5% as large a surface area, located in a low-SAV soil.
Carbon steel (above-ground, coated)	Delays onset of corrosion by N(9,3). Then it corrodes like a low-SAV, underground tank with a failed coating, and 5% as large a surface area.

Carbon steel (underground, impressed current cathodic protection)	PACE baseline after mN(10,5) years
Carbon steel (underground, impressed current cathodic protection, coated)	Delays onset of corrosion by max [mN(10,5), N(7,3)]. Then it corrodes like a similar coated tank whose coating has failed.
Stainless steel	Corrosion rate of 25% of that applicable to steel.
Fiberglass	No corrosion
Concrete	Gradually disintegrates due to chemical attack, but this effect has been included with ruptures.

- Sources and Explanations:

Carbon steel (underground, unprotected): PACE

Carbon steel (underground, coated): Corrosion will not begin until the coating has failed. The coating is assumed to fail according to a normal distribution, N(7,3). The 7-year mean was obtained from A.H. Roebuck and G.H. Brevoort, "Coating Work Costs and Estimating," *Materials Performance*, 22(1): 43-47 (Jan. 1983). Standard deviations were estimated by doubling the reported variations between average coating lives in differing environments. In addition, the standard deviation was increased 50% to account for variations in sub-grade drainage and the possibility of scratches during installation. The coating used was 2-coat coal-tar epoxy with an SP10 (near white blast) surface preparation. The mean age to failure is that reported for coatings in a freshwater environment.

Once the coating has failed, there is a near certainty of localized corrosion at the points of failure, for those points present excellent point anodes. The time-to-failure distribution must therefore be adjusted to reflect the certainty of a point anode's existence. We do this by dividing each probability in the PACE baseline distributions by the corresponding year-30 failure probabilities. The following time-to-failure distributions therefore apply following coating failures:

Tank Age	Low SAV(%)	Medium SAV(%)	High SAV(%)
4	0	0	0
9	0	14.5	32.0
14	9.0	38.0	59.9
19	34.3	70.9	91.8
24	69.1	87.9	95.9
30	100.0	100.0	100.0

Carbon steel (aboveground, uncoated). We assume that above-ground tanks only experience localized corrosion at their seams and their points of contact with cradles. These areas account for approximately 5% of their surfaces. We assume that air is about as corrosive as a low-SAV soil. Thus, these tanks corrode like low-SAV, underground tanks of 5% as large a surface area. The effect of area on corrosion rates is discussed below under "variations."

Carbon steel (aboveground, coated). The coating lifetime was based on Roebuck and Brevoort's values for exterior coatings in a moderate atmosphere. The result is a coating lifetime at N(9,3). Once the coating has failed, the tanks will have a 100% chance of developing point anodes (at the sites of initial coating failure), and will corrode like underground, coated tanks of 5% the surface area, in a low-SAV environment.

Carbon steel (underground, impressed current cathodic protection). We chose impressed current as the preferred means of cathodic protection on the recommendation of the National Association of Corrosion Engineers (NACE) (Houston, phone conversation). This recommendation was given because such a system can be repaired without excavation. Furthermore, a crude check of its functioning can be done merely by observing the ammeter.

The components of such a system are crucial. The wiring is not subject to protection, so it is failure-prone. The rectifier is also subject to failure, especially if much energy is dissipated. In addition, cathodic protection can fail if the local electrical environment changes (*e.g*. interference with another protected system across the street, or if someone buries some unprotected metal nearby).

Impressed-current cathodic protection therefore requires an inexpensive check of current distribution every 2-3 months (6 months maximum). This can be done by a contractor equipped with a hand-held meter, and takes only 2-3 minutes (plus travel).

With regular maintenance, NACE says such a cathodic protection system should last for a long time. No failure data appears to be available, however, and NACE says failures are common among poorly-maintained systems. We therefore assume that cathodic protection systems fail with a distribution of (m)N(10,5), where m is a random number drawn from (1, 3) indicating the stochastic quality of the maintenance effort. (1 means no maintenance). Source: BEJ following phone conversations with NACE.

As long as cathodic protection is functioning, corrosion will be negligible.

If cathodic protection fails and is repaired after a substantial interval, it may be too late to restore complete protection. Cathodic protection does not function well for creviced surfaces (or pits), for it is difficult to get an adequate charge density. (Source: NACE/API, Corrosion of Oil-and Gas-Well Equipment (1958), p. 71.) Since belated repair will be insufficient to halt established localized corrosion, we have not modeled belated repairs of the cathodic protection system. Ordinary maintenance, however, is already included in our time-to-failure distriution.

Carbon steel (underground, impressed current cathodic protection, coated). If cathodic protection and a coating are both used, both the cathodic protection system and the coating must fail before corrosion will occur. Once failure occurs, point anodes will exist at the points of coating failure.

Stainless steel. Stainless steel corrodes four times more slowly than unprotected carbon steel. Source: Peters & Timmerhaus, Plant Design and Economics for Chemical Engineers, 3rd. Ed., (1980), p. 574.

Concrete. The disintegration of concrete leads to cracking, not to localized corrosion holes. We will discuss the cracking of concrete tanks under ruptures, event T1124, below.

VOLUME OF RELEASE:

- Tank corrosion represents a growing leak. Eventually the leak rate will reach a detectable level.

ASSUMPTIONS:

- Corrosion holes start small. Assume initial hole size follows a beta distribution, with a minimum size of (1/64)", a maximum of (1/4)", and a mode of (1/32)".
- Corrosion holes grow with time. We use the corrosion rate, r, calculated earlier, as the base rate at which corrosion holes grow in radius. In addition, once exterior corrosion holes have perforated the tank, they will also grow because of generalized interior corrosion (see event T1125). We therefore add this corrosion rate to r in order to determine the total rate at which the hole grows in radius.
- Corrosion holes may occur anywhere on the tank. Depending on such factors as water table depth, they may be more likely to occur on the bottom of the tank. We have decided to assume that the average corrosion hole occurs on the tank bottom. This estimate could be refined to account for fluctuations in fluid levels and the fact that leak rates are not linearly dependent on hydraulic head. Such refinements greatly complicate the model, however, without significantly altering the leak rates. Hence, we use simple "average" hydraulic heads throughout the model, rather than integrating loss rates over the cyclical fluctuations in fluid depths.
- For storage tanks, we assume that the average fluid depth is 50% of the tank height. For treatment tanks we assume that the average fluid depth is 80% of the tank height.

- For underground tanks, the leak rate is calculated according to the underground leak rate formula. (Section A.1.1). For above-ground tanks or tanks in vaults, the Bernoulli equation (Section A.1.2) applies.

VARIATIONS:

- Tank capacity. Localized external corrosion is an electrochemical process which will only occur if the tank surface experiences a non-uniformity which can function as a locale for electrochemical attack. Such non-uniformities are referred to as "point anodes" and may consist of scratches in the tank wall, variations in local soil conditions, or stones or cinders in contact with the tank wall.

  Logically the probability that point anodes will be present is a function of tank surface area: the larger the tank, the higher the probability that a point anode exists. Similarly, the larger the tank surface area, the more likely it is that there is an unusually active point anode somewhere on the tank surface.

  The easiest way to account for this factor is to adjust the corrosion rate r to account for the surface area of the tank. According to a pipe corrosion model by Rossum (see event B13 for a full discussion), the corrosion rate for the deepest pit is proportional to the .16 power of the surface area. Therefore, variations in tank size can be accounted for by adjusting r according to the following formula:

  $$r = r_0 \, (A/A_0)^{.16}$$

  where

  r = the adjusted corrosion rate
  r_0 = the corrosion rate obtained from the PACE data
  A = the surface area of the tank under consideration and
  A_0 = the average area of the tanks included in the PACE study

  These tanks were all service station tanks, many of which were installed prior to 1970; they probably averaged 5000 gallons in capacity. The surface area of such tanks is approximately 440 square feet.

  This area adjustment factor applies to coated tanks and stainless steel tanks as well as to carbon steel tanks, for in all cases, an increase in tank surface area increases the probability that there is an unusually active pit.

- Stray currents can accelerate corrosion. Approximately 10% of tanks are subjected to stray currents due to nearby electrical equipment or electrical rail lines. (Source: Warren Rogers, Warren Rogers Associates, personal communication.) Stray currents approximately double external corrosion rates. (Source: Warren Rogers, Warren Rogers Associates, personal communication.) In order to allow greater variability in this effect, we have assumed that stray currents multiply the corrosion rate r by a stochastic factor of x. x is distributed according to a beta distribution with a minimum of 1, a mode of 2, and a maximum of 4.

- If the leak is detected, the tank will be repaired or replaced, and the aging process will start over again, using the same parameters as those used for the original tank.

- Cathodic protection will have no effect on hole growth rates; once the cathodic-protection system has failed, the tank will corrode in the same mann as an unprotected tank.

- Coatings will also have no effect on hole growth rates.

- Double-walled tanks: The 2 walls of such tanks are modeled separately. Exterior corrosion attacks the outside of the outside wall. Interior corrosion attacks the inside of the inside wall. The interstitial space is not subject to corrosive attack. The interstitial alarm is modeled as a leak detector similar to that used in a vault. See event MOALARM, below.

- In-ground tanks or above-ground tanks on-grade. Both the above- and below-ground sections of such tanks are subject to corrosion. Because exterior corrosion is more rapid below-ground than above-ground, however, we have only modeled exterior corrosion of the below-ground segment. Similarly, since interior corrosion is most important on the bottom of the tank, we have only modeled interior corrosion of the tank bottom.

USER INPUTS:

- Tank surface area
- Corrosion protection methods employed
- Tank material
- Soil characteristics
- Rate of generalized interior corrosion (from event T1125)
- Tank wall thickness
- Tank location (above-, below-, or in-ground)
- Is the tank double-walled?

HAZARDOUS WASTE TANKS

LABEL: T1123

FAILURE: Localized interior corrosion

SOURCES:

- API Tank and Pipe Leak Survey (referenced in SCS Engineers, "Assessment of the Technical, Environmental, and Safety Aspects of Storage of Hazardous Waste in Underground Tanks," Draft, 1983).
- PACE corrosion study, cited under event T1121.
- Best engineering judgment.

ASSUMPTIONS:

- Interior corrosion leaks are the same size and grow at the same rate as exterior corrosion holes.
- Volumes are larger, however, for the hole usually occurs at the bottom of the tank and therefore has more hydraulic head than that assumed for exterior corrosion holes.

CALCULATIONS:

- Using SCS Engineers' analysis of API survey data, we can construct the following tabulation of underground tank leaks:

Source of Leak	# of Failures	% of Total	Scaled to 77%
- TANKS			
localized exterior corrosion 776 + 212	988	61.6	77.0%
interior corrosion	194	12.1	15.0%
other	55	3.4	4.3%
loose fitting	9	0.6	0.8%
breakage	17	1.1	1.4%

- PIPES & ANCILLARY			
pipe corrosion	353	22.0	27.5%
loose pipe fitting	64	4.0	5.0%
flex connector	38	2.4	3.0%
breakage	43	2.7	3.4%
other	54	3.4	4.3%
	1603		

- Explanation:

  - We obtained the last column by scaling the first entry to 77%. We then multiplied the remaining entries in this column by the same scaling factor. This scaling factor is based on Warren Rogers' assertion that 77% of all tanks exhibit significant localized exterior corrosion. This percentage is also consistent with the PACE data, which show that 76.6% of medium-SAV tanks have leaked by year 30. Due to the possibility that a tank system may experience more than one type of failure, the numbers in this column do not sum to 100%.

  - Line 1 includes 212 tanks that were not reported as failing by localized exterior corrosion. We included these tanks because we assumed that localized exterior corrosion is a slower process than the other four forms of tank failure. Thus, we assume that 77% of the 275 tanks that failed by these other mechanisms were undergoing undiscovered localized exterior corrosion at the time they failed. We make no similar adjustment to account for tanks that might have been undergoing localized exterior corrosion at the time of piping failures, because we assume that tank and piping systems are repaired independently. Thus, the API survey data already account for systems which suffer both tank and piping failures.

- We can read the following results off the above table:

Failure Mechanism	Probability	Conditional Distribution
exterior tank corrosion	0.77	See event T1121
interior tank corrosion	0.15	See below
seam leaks (the most likely form of "other")	0.043	See event T1124
tank rupture (breakage)	0.014	See event T1124
pipe corrosion	0.28	See event B13

pipe rupture (breakage)	0.034	See event B11
loose fittings	0.05	See event B121

PROBABILITY DISTRIBUTION: Conditional normal

PROBABILITY:

- .15c where c is a material-dependent coefficient given by the following table:

Tank material	c
steel	1
stainless steel	1
fiberglass	0
concrete	0

Coefficient c merely indicates that fiberglass does not corrode and that instead of treating the aging of concrete as corrosion, we will treat it as contributing to rupture under event T1124, below.

TIME-TO-FAILURE:

- We estimate that localized interior corrosion should occur more quickly than localized exterior corrosion. Since the PACE data show that the conditional mean date of localized exterior corrosion failure for tanks in medium-SAV soils is approximately 16 years, we assume that localized interior corrosion proceeds twice as fast. Thus, for quarter-inch steel, we have assigned a localized interior corrosion time-to-failure distribution of N(8,5). In choosing this distribution, we have used a relatively large standard deviation in order to cover unknown factors, including variations in yearly flow rates.

- Let x be the failure date sampled from N(8,5). Since the typical service station tank is .25" in thickness, the corrosion rate (r) for those tanks which experience localized interior corrosion is given by:

$$r = \frac{.25}{x}$$

In deriving this equation, we have assumed that localized interior corrosion was the primary corrosion mechanism for those tanks listed as failing by interior corrosion.

- We can now compute the failure date by using the combination of localized interior corrosion and generalized exterior corrosion to keep track of remaining wall-thickness. Because generalized exterior corrosion is usually much slower than localized interior corrosion it usually has only a minor effect on the date of failure. For this reason, we did not account for it in calculating our corrosion rate r, above. Generalized exterior corrosion is only important in those cases when it occurs unusually quickly.

VOLUME:

- Interior corrosion holes begin with the same size distribution as exterior corrosion holes, and grow in radius at the rate r calculated above.

- In addition, corrosion holes will also grow due to the effects of generalized exterior corrosion. See event T1126, below.

- Interior corrosion leaks tend to occur at the bottom of the tank. For storage tanks, we assume that the tank is on average 50% full; for treatment tanks, we assume that it is 80% full.

- For underground tanks, we calculated leak rates according to the underground leak rate equation (Section A.1.1). For above-ground tanks, tanks in vaults, or the above-ground sections of in-ground or on-grade tanks, the Bernoulli equation (Section A.1.2) applies.

VARIATIONS:

- Coated steel. We assume that the coating is 3-coat epoxy. Then the distribution of coating failure times is N(7,3). Source: Roebuck and Brevoort (1983). Corrosion will not begin until the coating fails. We assume that the failure of interior coatings does not influence either the probability of corrosion or the corrosion rate for interior corrosion. Thus tanks with failed interior coatings experience interior corrosion in the same manner as new, uncoated tanks.

- Cathodic protection. Cathodic protection has the same effects and the same time-to-failure distribution for interior corrosion as it has for exterior corrosion. We have assumed that when the exterior cathodic protection system fails, the interior cathodic protection system also fails.

- Double-walled tanks. See event T1121.

- Tank capacity. Unlike localized external corrosion, localized interior corrosion is not likely to be correlated with tank capacity. Localized internal corrosion is most likely to occur beneath the fill tube, and the affected area is likely to be influenced by factors such as method of filling or pumping rate, rather than tank size.

- Stainless steel tanks. Stainless steel tanks corrode at 25% of the rate applicable to carbon steel.

USER INPUTS:

- Rate of generalized exterior corrosion
- Tank material
- Tank wall thickness
- Type of corrosion protection system

HAZARDOUS WASTE TANKS

LABEL: T1124

FAILURE: Tank Rupture

ASSUMPTIONS:

- Tank rupture can occur from inadequate component strength, settling, or exterior force.
- Tank rupture includes both large cracks and seam leaks.

SOURCES: See T1123 (Breakage + "other")

CALCULATIONS:

- SCS/API data (see event T1123) indicates a tank rupture rate of 1.4%.
- SCS/API data indicates a seam leak rate of 4.3%.
- SCS/API data indicates an average tank age of 10.8 years.
- Assuming ruptures are approximately uniformly distributed over the 10.8 years of tank lifetime, the average annual probability of ruptures is 5.7%/10.8 yrs = 5.3×10^{-3}/yr.

PROBABILITY: 5.3×10^{-3}/yr

PROBABILITY DISTRIBUTION: Binomial

VOLUME:

- Ruptures may take 2 forms: large cracks and seam leaks. The data from event B13 indicate that 75% of ruptures are seam leaks, while 25% are large cracks.
- Seam leaks are assumed to range in length from 0 to 5 ft, and in width from 0 to (1/16)".
- Large cracks are assumed to range in length from 3" to 36" and in width from 0 to 3".

VARIATIONS:

- Aboveground, in-ground, or vaulted tanks. Above-grade ruptures occur because of different types of accidents than occur for below-ground tanks. Vehicle collisions, collisions with fork-lifts, and inadequate component strength are major causes of ruptures. We assume that the probability of rupture is still 5.3 x 10^{-3}. Volume of loss will be limited by the amount of fluid in the tank.

- Fiberglass tanks. Fiberglass tanks are approximately twice as likely to rupture as steel. The probability of rupture is therefore 1 x 10^{-2}/yr. Source: Brown Minneapolis Tank Co., personal communication 4/30/85. Brown Tank Company said that 2% of fiberglass tanks collapse in the first couple of years. We obtained our scaling factor of 2 by comparing that percentage to the .5% annual probability of steel tank rupture.

- Double-walled tanks. We assume that since the inner wall of a double-walled tank is subject to fewer stresses than is the wall of a single-walled tank, it is only 50% as likely to rupture. The outer wall of such a tank, though, is likely to be just as vulnerable to rupture as the wall of a single-walled tank. We assume, however, that there is only a 50% chance that a rupture of the outer wall will also breach the inner wall. Since ruptures of the inner wall do not involve large exterior forces (such as vehicle collisions or settling of the backfill), we assume that the number of times that interior ruptures also breach the outer wall is small enough to be ignored.

  When a rupture of a double-walled tank occurs, infiltrating soil moisture or leaking hazardous waste will trigger the interstitial alarm. There is a 10% probability that the alarm will fail to function. See MOALARM, below.

LABEL: T1125

FAILURE: Thickness loss due to generalized interior corrosion.

ASSUMPTIONS:

- This event will cause a loss when remaining wall-thickness reaches zero.
- This event will also reduce the time it takes for localized exterior corrosion holes (if any) to penetrate the tank.

SOURCES: Perry and Chilton (1973).

CALCULATIONS:

- According to Perry and Chilton, generalized interior corrosion rates of .002"/yr to .02"/yr are reasonable. We expect that the lower corrosion rates are the most likely.

VOLUME: See event T1123.

PROBABILITY DISTRIBUTION: Uniform

PROBABILITY:

Cumulative Probability	Corrosion Rate
0.00 to 0.65	0.002"/yr
0.65 to 0.90	FNU(.002,.01)
0.90 to 1.00	FNU(.01,.02)

VARIATIONS:

- Coatings. See event T1123.
- Cathodic protection. See event T1123.

HAZARDOUS WASTE TANKS

LABEL: T1127

FAILURE: Thickness loss due to generalized exterior corrosion.

ASSUMPTIONS:

- This event will reduce the time it takes for interior corrosion holes (if any) to penetrate the tank, as well as increasing the rate of interior hole growth once a hole occurs.

SOURCES:

- "Prediction of Leaks in Unprotected Storage Tanks," Warren Rogers Associates, Inc., included in correspondence package from Betsy Tam, EPA, to Chris Lough, PRA.
- W. H. Ailor, Atmospheric Corrosion (John Wiley and Sons: New York) 1982, p. 33.

CALCULATIONS:

- According to Ailor, generalized corrosion in an air environment occurs at approximately 1.4 mils/yr.
- According to Warren Rogers Associates, generalized corrosion is unlikely to cause failure (for a quarter-inch tank) within the 40-year time-horizon of their data.
- Generalized external corrosion in a soil environment is unlikely to occur more slowly than in air. 1.4 mils/yr is therefore a minimum value for the generalized external corrosion rate.
- 5 mils per year is a suitable upper bound for the generalized corrosion rate. This choice correspondes to a 50-year minimum time-to-failure for quarter-inch steel tanks in non-extreme environments.
- SAV will have some effect on generalized corrosion. Assuming the effect is roughly linear, and noting that according to the Canadian data the average SAV is 10, we account for SAV by a multiplying the generalized exterior corrosion rate by SAV/10. Under no circumstances, however, do we use a generalized corrosion rate of less than 1.4 mils/yr.

CORROSION RATE:

$$r_{gen,\ ext} = \max\left[.0014, \left(\frac{SAV}{10}\right) FNU\ (.0014,\ .005)\right]$$

where

$r_{gen,\ ext}$ = the generalized external corrosion rate.

VARIATIONS:

- Direct currents will have the same effect on generalized exterior corrosion as they have on localized exterior corrosion.
- Stainless steel tanks will corrode at one-fourth the rate applicable to steel tanks. See event T1121.
- Above-ground tanks. The atmospheric corrosion rate of 1.4 mils/yr applies (or one-fourth of that for stainless steel tanks).
- Cathodic protection or coatings. Significant generalized exterior corrosion will not begin until corrosion protection fails. Since generalized exterior corrosion is not influenced by the presence of point anodes, we assume that once the coating has failed, generalized exterior corrosion proceeds in the same manner for coated and uncoated tanks.

HAZARDOUS WASTE TANKS

LABEL: T1128

FAILURE: Tank fails due to generalized corrosion.

ASSUMPTIONS:

- Tank corrosion may occur generally, due to a combination of rapid generalized exterior and generalized interior corrosion.

CALCULATION:

- Tank wall-thickness must be computed even for tanks without localized corrosion. In a few cases, this will produce corrosion failure.

VOLUME:

- We determine the sizes and the growth rates for these holes in the same manner as we determine the sizes and growth rates for localized corrosion holes.

LABEL: B11

FAILURE: Pipe Rupture

SOURCES: SCS Engineers' analysis of API data (see event T1123).

CALCULATIONS:

- According to the API data, 3.4% of service station tanks experienced pipe rupture. (See the table entry labeled "breakage" in event T1123).
- These tanks had been in use an average of 10.8 years.
- The annual rupture probability is therefore 3.4%/10.8 = 3.15×10^{-3}/yr.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: 3.2×10^{-3}/yr

VOLUME:

- We assume minimum and maximum crack sizes of 1" x .1" and 10" x (1/4)", respectively.
- We assume that rupture dimensions are uniformly distributed over the range of possible values. Therefore:

  width = FNU(.1,.25) inches
  length = FNU(1,10) inches

- We determine hydraulic heads by applying the pipe-pressure formula (Section A.1.5) to the geometry of the system design under consideration. We assume that the rupture occurs at the midpoint of the pipe.
- Loss will only occur during filling or discharging. We calculate fill/discharge duration according to Section A.1.6.

VARIATIONS:

- Pipe length and system geometry will vary with system design.
- Above-ground pipes or pipes in vaults. We assume that the rupture probability for above-ground pipes is the same as that for underground pipes. We also assume that the hole size distributions are the same for both types of pipes.
- Fiberglass pipes. The probability of rupture is doubled. See event T1124.
- Multiple pipes. We evaluate each pipe separately. We assume that the rupture of one pipe has no influence on the probability that other pipes will also rupture.

USER INPUTS:

- System geometry
- Pipe diameter
- Pipe length

LABEL: B121

FAILURE: Welded Flange Leak

SOURCES:

- Nuclear Regulatory Commission, Reactor Safety Study (1975).
- Henley and Kumamota (1981).
- SCS Engineers (1984).

ASSUMPTIONS:

- A flange leak can only occur when fluid is in contact with the flange. If the flange is located at the top of the tank, fluid only contacts it during filling, discharging, or overflow. If the flange is at the bottom of the tank, fluid will always be in contact with it. The location of the flange is dependent on system design.

CALCULATIONS:

- 3×10^{-7}/hr = welded flange leak rate (Reactor Safety Study).
  3×10^{-7}/hr = .003/yr
- 10^{-4} to 10^{-1} per 10,000 hrs = welded flange leak rate (Henley & Kumamoto).
  10^{-4} to 10^{-1} per 10,000 hrs = 8.8×10^{-5} to 8.8×10^{-2}/yr. The geometric mean of this range of values = .0028/yr.
- API service station data gives a loose fitting rate of 5.0% (SCS Engineers). The average system age is 10.8 yrs. The failure rate is therefore 5.0%/10.8 = 4.6×10^{-3}/yr.
- We therefore use a conservative flange leak probability of 5×10^{-3}/yr.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: 5×10^{-3}/yr

VOLUME:

- The flange is at the point of attachment of the pipe to the tank.
- The pressure drop due to friction losses therefore includes the entire length of the pipe.
- The elevation change can be calculated from the system geometry.
- We assume a 50% weld failure as upper bound, 0 as lower bound. I.e., we assume that the length of the breach is distributed according to FNU(0, 50% of flange circumference). We assume that the width of the breach is given by FNU(0,1/8) inches.
- We assume a 300 to 400 lb flange. The exterior flange diameter is 6.5". (Source: Perry and Chilton, Chemical Engineers' Handbook, 5th Ed. (1973), pp. 6-66 and 6-67, using a 2"-diameter pipe). The maximum weld failure is therefore 10" long.
- For underground flanges, we calculate the leak rate by using these values in the underground leak rate formula (Section A.1.1). For aboveground flanges (or flanges in an air environment such as a vault) we use the Bernoulli equation (Section A.1.2).
- We calculate the loss per day by multiplying the leak rate by the length of time that the fluid is in contact with the flange.

VARIATIONS:

- Flange location. A flange may be at the top of the tank or near the bottom of the tank. Its location will influence the hydraulic head of the fluid and will determine the fraction of the time that the flange is in contact with fluid. The flange location will be determined by the choice of system design.
- Multiple flanges. We evaluate each flange independently. Thus, we assume that the failure of one flange has no influence on the probability that other flanges will leak.

USER INPUTS:

- System design

LABEL: B122

FAILURE: Gasket Fails

ASSUMPTIONS:

- We model gasket deterioration as an erosion-like process. We assume that under ideal conditions, it will occur relatively slowly, at a rate of less than 50 mils per year.

SOURCE:

- Best engineering judgment based on Nuclear Regulatory Commission, Reactor Safety Study (1975), and EPA, Case Studies 1-23 (1984) (case study #4).

PROBABILITY DISTRIBUTION: Empirical

PROBABILITIES (baseline):

Cumulative Probability	Deterioration Rate (mils/yr)
0.00 to 0.77	FNU(0,12.5)
0.77 to 0.83	FNU(12.5,25)
0.83 to 1.00	FNU(25,50)

DATE OF FAILURE:

- For a 2" pipe, the standard gasket is a flat disk with an inner radius of 1" and an outer radius of 2.0625". Since disintegration occurs from the inside outward, 1.0625" of gasket must be dissolved or eroded before the fluid can escape. A gasket for a 4" pipe is slightly thicker (1.4375"). (Source: Perry and Chilton, 1973).

VOLUME: See event B121 (welded flange leaks).

COMMENTS:

- o Under ideal conditions, we have assumed that a gasket will deteriorate very slowly. Waste/gasket interactions will speed up the deterioration process, however. To model such interactions we use a multiplicative factor selected from FNU(1,20). Gasket failure can therefore occur as early as year 2. This is consistent with the facts of EPA case study number 4 (Biocraft site).

- The Reactor Safety Study quotes a failure rate for containment-quality gaskets of 3×10^{-6}/hr = 2.6%/yr. This may be too low for a conventional hazardous waste tank system, but it serves as an approximate check for the results of our gasket disintegration model.

LABEL: B13

FAILURE: Pipe Corrosion

SOURCES:

- John R. Rossum, "Prediction of Pitting Rates in Ferrous Metals from Soil Parameters, Jour. AWWA, 1969, pp. 305-310.
- PACE (see event T1121).
- SCS Engineers analysis of API survey data (See event T1123).

PROBABILITY DISTRIBUTION: Cumulative Empirical

CALCULATIONS (underground pipes):

- Localized exterior corrosion

  Rossum gives the following formula for maximum exterior pit depth for buried steel pipes:

$$p = 1.06K_n\left[\frac{(10\text{-pH})t}{\rho}\right]^n A^{.16}$$

where

p = the depth of the deepest pit (in mils)

K_n = 170 for soils of good aeration
= 222 for soils of fair aeration
= 355 for soils of poor aeration

pH = the soil pH (must be between 5 and 9)

n = 1/6 for soils of good aeration
= 1/3 for soils of fair aeration
= 1/2 for soils of poor aeration

= the soil resistivity (ohm-cm)

t = the number of years since the pipe was buried

A = the surface area of the pipe (in square feet)

We have added a fourth aeration category, moderate aeration. We obtained K_n for this category by averaging the values for good aeration and fair aeration. We obtained the value of n by taking the geometric mean of the values for good and fair aeration. Thus:

K_n = 196 for soils of moderate aeration

n = .236 for soils of moderate aeration

- Multiple failures. Unlike our tank-corrosion model, which only predicts the date of first failure, the Rossum pipe-corrosion model can be used to determine the occurrence of subsequent corrosion holes. The number of leaks (L) at time t is given by:

$$L = A\left[\frac{1.06K_n}{z}\right]^{6.25}\left[\frac{t(10-pH)}{\rho}\right]^{n/.16}$$

We make this formula stochastic by converting fractional values of L into probabilities. Thus, we have assumed that the first leak occurs between L = 0 and L = 2. At L = 1, there is a 50% chance of failure. Similarly, the second leak occurs between the times when L = 1 and L = 3, the third leak between L = 2 and L = 4, etc. This means, for example, that a value of L equal to 3.2 means that 2 leaks have occurred with certainty; there is a 60% chance that a 3rd leak has occurred, and if the third leak has occurred, there is a 10% chance that the 4th leak has also begun.

Note that the value of t is set to zero whenever detection/repair occurs.

Caveat: The Rossum model applies only for soil pH between 5 and 9. Outside that range, other corrosion mechanisms come into play. These are not included in our model.

- Generalized interior corrosion. When fluid is in contact with the pipe, we assume that generalized interior corrosion occurs under the same probability distribution as applies to tanks. Because these are independent events, however, we determine the corrosion rates separately for each tank and each pipe. When the pipe is in contact with air, we use a corrosion rate of 1.4 mils per year (Ailor, 1982). When we combine corrosion from the fluid and corrosion from the air, we obtain a generalized interior corrosion of:

$$1.4(1-f) + f(r')$$

where

f = the fraction of time the pipe is in contact with the fluid

r' = the corrosion rate obtained for those times when fluid is present

Caveat: The Rossum model applies only for soil pH between 5 and 9. Outside that range, other corrosion mechanisms come into play. These are not included in our model.

- Localized interior corrosion. Since our tank-corrosion model shows that localized interior corrosion is 19% as likely as localized exterior corrosion, we assume that the same ratio applies to pipes. We cannot use this information directly, however, because our localized exterior pipe-corrosion model only applies if soil conditions are known. We therefore must use API service station data to determine the probability that pipes undergo localized interior corrosion. From this, we can then obtain the probability of localized interior pipe corrosion.

  According to the API data, 28% of service station tanks experience pipe corrosion. Since service station tanks generally have two pipes, we convert this value to a per-pipe probability by assuming that corrosion is equally likely in either set of piping. Thus, letting "a" be the probability of localized corrosion for a single pipe, it must be the case that:

  $$.28 = 1 - (1-a)^2$$

  or, a = .15. Thus, if localized interior pipe corrosion is 19% as common as localized exterior pipe corrosion, and if other forms of corrosion failure are uncommon, then approximately 2.4% of the API survey pipes failed by localized interior corrosion, while 12.6% failed by localized exterior corrosion.

  We assume that the time-to-failure distribution for localized interior corrosion is the same for pipes and tanks. Thus, the time-to-failure distribution for those pipes which exhibit localized interior corrosion is N(8,5).

  We adjust for area by multiplying both the probability of localized corrosion and the corrosion rate by $(A/10)^{.16}$. See the discussion of above-ground pipes, below, for an explanation of this area correction factor.

- Generalized exterior corrosion. Generalized exterior corrosion reduces the time to pipe failure by localized interior corrosion in the same way that it reduces the time to interior corrosion failure for tanks. We assume that generalized exterior corrosion rates for pipes follow the same probability distribution as applies to tanks. See event T1127.

- Erosion. Because pipes carry moving fluids, they are subject to erosion by suspended solids in the waste. Erosion rates are dependent on the concentration of suspended solids. Since our baseline corrosion values are derived for pipes carrying a non-erosive fluid (gasoline), we assume that they do not already account for erosion. We therefore add the following erosion rates to both our localized interior and generalized interior corrosion rates:

Fraction of suspended solids in the waste (ppm)	Erosion rate (mils/yr)
<1,000	0
1,000-10,000	FNU(0,5)
>10,000	FNU(5,10)

VOLUME OF RELEASE:

- We assume that localized exterior corrosion holes follow the same size distribution for pipes as they do for tanks. We calculate their growth rates in the same manner as we calculate growth rates for exterior corrosion holes in tanks.

- Localized interior corrosion holes also follow the same size distribution and grow in the same manner as do the corresponding holes in tanks.

- If the pipe fails due to generalized corrosion, the holes will be larger than they will be for localized corrosion. We assume that such holes begin with the dimensions of a pipe rupture (see event B11), and double in length and width each year until they are detected. In order to account for the physical limitations imposed by the dimensions of the pipe, we do not allow such corrosion holes to become more than 3" wide or longer than the length of the pipe.

- We calculate fluid velocity, transfer time, and pressure in the same manner as we used for underground pipe ruptures. For both corrosion holes and ruptures, we make the simplifying assumption that the leak occurs at the midpoint of the pipe.

- We use the underground leak rate equation (Section A.1.1) to calculate loss rates. Multiplying this leak rate by the fill or discharge time (Section A.1.6) then gives the total volume of loss per filling or discharging.

ABOVE-GROUND PIPES:

- The Rossum Model does not apply to above-ground pipes.

- Localized exterior corrosion. We obtain the localized exterior corrosion rate for above-ground pipes from the following conditional normal distribution:

$$.11\left(\frac{.05A}{10}\right)^{.16}\left[N(16(10/.05A)^{16},\ 6.6(10/.05A)^{.16}\right]$$

  where

A = the surface area of the pipe in square feet.

- Interpretation. The first term of this formula, $.11(.05A/10)^{.16}$ is the probability that localized exterior corrosion occurs. The $(A/10)^{.16}$ factor is the same area adjustment factor that we use for tanks, except that for pipes, the baseline area is 10 square feet. This area corresponds to 20 feet of 2" pipe or 10 feet of 4" pipe. These pipe dimensions are appropriate for service station fill and discharge pipes, respectively.

  The .11 coefficient in this expression is the baseline probability of localized exterior corrosion. We derived this probability from a combination of the PACE tank data and the API pipe-corrosion data. According to the PACE data, 70% of low-SAV tanks fail by localized exterior corrosion within 30 years, while 77% of medium-SAV tanks fail by that mechanism in the same period. According to the API data, 12.6% of service station pipes fail by localized exterior corrosion. If we assume that this percentage applies to medium-SAV soils and that the same proportionality factor applies to low- and medium-SAV pipes as applies to low- and medium-SAV tanks, then (70/77) x 12.6% of low-SAV service station pipes fail by localized exterior corrosion. To two significant figures, this percentage is 11%. If we assume that above-ground pipes corrode like low-SAV underground pipes (an assumption similar to that which we made for above-ground tanks) then we can apply this percentage to above-ground pipes.

  The second part of our localized exterior pipe-corrosion formula, $N(16(10/A)^{.16}, 6.6(10/A)^{.16})$, gives the conditional date of failure for pipes that experience localized interior corrosion. The factor $(10/A)^{.16}$ reduces the time to failure according to the inverse of the area adjustment factor. Thus, when a corrosion rate is calculated from the sampled time-to-failure, that corrosion rate will be higher than baseline by a factor of $(A/10)^{.16}$.

  Our baseline time-to-failure distribution in this expression is N(16,6.6). We derived this distribution in the same manner as we derived the 11% baseline probability of failure. According to the API survey data, service station pipes show the following distribution of failure dates:

Year of failue	Percentage of reported pipe failures
0-1	2.1
2-5	6.4
6-10	32.8
11-15	33.1
16-20	18.1
21-25	5.0
26-30	2.3
30+	0.2

We can approximate this distribution as N(12,5). Assuming that this distribution applies to medium-SAV pipes, we can obtain a low-SAV time-to-failure distribution by comparing the PACE distributions for medium- and low-SAV tanks. These distributions show conditional mean dates of failure of 21 and 16 years, respectively. Adjusting both parameters of the API distribution by 21/16 gives us a low-SAV time-to-failure distribution of N(16,6.6).

The final element of our above-ground localized corrosion formula is the .05 factor used to reduce the effective surface area of the pipe. We use this factor because we assume that like above-ground tanks, above-ground pipes are only vulnerable to localized exterior corrosion at their seams and points of support. These regions account for approximately 5% of their surface areas.

In our pipe-corrosion distribution, we have applied the area adjustment factor to both the baseline probability and the baseline corrosion rate. This is different from the way that we adjust for area in our tank corrosion model, for in that model, we only applied our area adjustment factor to corrosion rates.

We have modeled pipes and tanks differently because we believe that three factors control the onset of localized corrosion. One of these is the surface area of the buried metal. The others are the corrosivity of the soil and the care with which the component is installed. We have assumed that surface area is an important factor for localized corrosion events with low probabilities. In other words, we have assumed that the probability of pipe corrosion is relatively low because a pipe is small enough that it is relatively unlikely to experience a point anode. For tanks, however, the baseline probabilities of localized corrosion are on the order of 70-85%. We assume therefore, that the principal factors influencing the onset of tank corrosion are the corrosivity of the soil and the care with which the tank is installed. Surface area will be important, but its primary effect will be to determine the number of point anodes and thus the depth of the deepest pit.

We have generalized the preceding discussion to obtain the following rule of thumb: whenever the baseline probability of a corrosion event is less than 50%, we have assumed that component surface area will influence the probability of the onset of corrosion; whenever the baseline corrosion probability is over 50%, we assume that the component is already large enough that surface area has little influence on probability. Since all of our relevant baseline probabilites are either greater than 70% or less than 12%, we never had to elaborate this rule of thumb by developing a model to deal with intermediate cases. In addition, since our area adjustment factor requires an area more than 5000 times larger than baseline to increase a 12% probability to 50%, we did not need to modify that factor to assure that our area adjustments do not increase the probability of failure to a value greater than 50%. Finally, our model is insensitive to any choice of cut-off probabilities between 25% and 70%, so it is unnecessary for us to be precise in our determination of what value in that range is the theoretically best choice.

- Generalized exterior corrosion. Generalized exterior corrosion for above-ground pipe segments occurs at the atmospheric corrosion rate of 1.4 mils/yr.

- Localized interior corrosion and generalized interior corrosion. The corrosion rates for these types of corrosion are the same for above- and below-ground pipes.

- Combinations of corrosion mechanisms. We take combinations of corrosion mechanisms into account in the same manner for pipes as we used for tanks. Thus, to determine the date of interior corrosion failure, we compute the remaining wall-thickness for the combination of localized interior corrosion and generalized exterior corrosion. To determine the date of exterior corrosion failure, we calculate the remaining wall-thickness from the combination of localized exterior corrosion and generalized interior corrosion. To determine the date of generalized interior corrosion, we calculate the remaining wall-thickness from the combination of the two generalized corrosion mechanisms. We do not combine generalized exterior and localized exterior corrosion (or generalized interior and localized interior) because we assume that our localized exterior corrosion rates already include both forms of exterior corrosion.

- Pipe thickness. Pipe thickness is directly included as a parameter in the Rossum localized exterior corrosion model. For our PACE- and API-derived corrosion rate formulas, we use a baseline pipe thickness of 190 mils, which is the average of the thicknesses generally used for 2" and 4" pipe (Peters and Timmerhaus (1980)).

- Hole sizes. We use the same hole-size distribution for above- and below-ground pipes. We calculate hole growth rates in the same manner for both types of pipes.

VARIATIONS (above- and below-ground):

- Coated pipes. When a coating fails, there is a 100% chance of point anodes developing at the sites of coating failure. Thus, once the coating fails, localized exterior corrosion begins with certainty. Because the Rossum model does not take this factor into account, we use the following baseline time-to-failure distributions for low-, medium-, and high-SAV pipes:

Soil type	Piping time-to-failure distribution following coating failure
Low SAV	N(16,6.6)
Medium SAV	N(12,5)
High SAV	N(9,4)

These distributions are derived from the PACE and API data sets. The derivation process for high-SAV pipes is the same as that described earlier for medium- and low-SAV pipes.

These distributions apply to 190-mil pipes. We model different pipe thicknesses using the same approach that we used to model variations in tank wall-thicknesses.

- Cathodic protection. We assumed that the entire tank facility uses a cathodic protection system powered by a single power supply. Thus, when that system fails and repairs are not undertaken within a reasonable time, cathodic protection fails for both the tank and the pipes. Cathodic protection failure is discussed under events T1121. As long as it is functioning, cathodic protection will prevent both interior and exterior corrosion.

- Loss rates from above-ground pipes or below-ground pipes with secondary containment. Leak rates in such circumstances will be controlled by the Bernoulli equation (see Section A.1.2).

- Stray currents. If stray currents exist, they will affect pipes and tanks similarly. See event T1121. Because stray currents are likely to be equally severe for all elements of a tank system, we only sample the stray current event once for the entire facility.

- Stainless steel. Stainless steel reduces all corrosion rates by a factor of .25.

- Fiberglass. Fiberglass pipes do not corrode.

USER INPUTS:

- Pipe material
- System design
- Corrosion protection system
- Pipe thickness
- Surface area of pipe
- Soil characteristics

LABEL: A11111

FAILURE: Strainer drain left open after maintenance (or during pump-out for storage or accumulation tanks).

ASSUMPTIONS:

- We assume that the minimum operator response time is 15 seconds.
- Because the operator is likely to be in the vicinity, we assume a maximum response time of 3 minutes. We therefore assume that the response time is distributed FNU(.25,3) minutes.
- Strainer maintenance occurs once per month.

SOURCES:

- JRB Associates (1982)
- Nuclear Regulatory Commission, Reactor Safety Study (1975)

CALCULATIONS:

- 1.7×10^{-3} per operation = operator failure rate for operations embedded in a procedure (JRB).
- This is a relatively infrequent procedure (once per month) with no immediate feedback. Therefore, 1×10^{-2} (general failure rate for operations with no status display) is probably a better figure (Reactor Safety Study).

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: 1×10^{-2}/month

VOLUME:

- We assume that the leak rate is equal to the pumping rate.

VARIATIONS:

- Storage and accumulation tanks. For many of these tanks, the strainer will be included as part of the pump-out truck. In such cases, error in strainer maintenance will be detected and corrected at the first pump-out following pump maintenance.

- We assume that the pump-out truck visits 40 tanks per month.
- Let n be the number of pump-outs per month for the modeled tank (n may be less than 1). Then the probability is n/40 that the facility is the first one to be visited after any given strainer maintenance. The annual probability of a spill due to faulty maintenance of the pump-out truck's strainer is therefore given by:

$$1 \times 10^{-2} \times (n/40) \text{ per month} = 3n \times 10^{-3}/\text{yr}.$$

USER INPUTS:

- Number of pump-outs per month (n)

LABEL: A11112

FAILURE: Pump drain left open during pumping.

ASSUMPTIONS:

- This can only happen following pump maintenance.
- Pump maintenance occurs annually.
- The response time in the event of a spill is FNU(.25,3) minutes.

SOURCES:

- Nuclear Regulatory Commission, Reactor Safety Study (1975)
- JRB Associates (1982)
- Event A11111 (strainer drain left open)

CALCULATIONS:

- See event A11111

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: 10^{-2}/yr

VOLUME:

- The spill rate is equal to the pumping rate.

VARIATIONS:

- Storage and accumulation tanks. For many of these tanks, the pump-out pump is included as part of the truck. An error in pump maintenance will therefore be detected and corrected at the first pump-out following pump maintenance.
- We assume that the truck visits 40 sites/month.

- Let n be the number of pump-outs per month at the facility being modeled. Then the probability that the facility being modeled is the first one to be visited after pump maintenance is n/40, and the probability that it is the first one visited after faulty pump maintenance is given by:

$$(1 \times 10^{-2})(n/40) \text{ per year} = 2.5n \times 10^{-4}/\text{yr}$$

USER INPUTS:

- Number of truck visits per month (n)

HAZARDOUS WASTE TANKS

LABEL: A1112

FAILURE: Hose ruptures (above ground) during pump-out (storage or accumulation tanks only).

ASSUMPTIONS:

- Hose ruptures inside the pump-out pipe will be inconsequential. Leakage will return to the tank in all but extraordinary circumstances.

SOURCES:

- JRB Associates (1982)

CALCULATIONS:

- Hose rupture probability = 1×10^{-4}/hr (JRB)
- Annual probability of hose rupture = 1×10^{-4}/hr x T hr/pump-out x n pump-outs/week x 52 weeks/yr = $5(nT) \times 10^{-3}$/yr

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: $5(nT) \times 10^{-3}$/yr

VOLUME:

- The maximum leak rate will be the pumping rate for the pump-out pump. The minimum is approximately 0.
- We assume that the leak rate is uniformly distributed between these two exremes.
- The maximum detection/response time is the entire discharge time (see Section A.1.6). The minimum detection/response time is about 15 seconds.

USER INPUTS:

- Number of discharges per week (n)
- Time required for pump-out (from Section A.1.6)

HAZARDOUS WASTE TANKS

LABEL: A1113, A1114

FAILURE: Pump or strainer ruptures during pump-out (storage or accumulation tanks only).

SOURCES:

- U.S. Coast Guard (1978)
- JRB Associates (1982)

CALCULATIONS

- 1 x 10^{-8}/hr = strainer rupture rate (JRB)
- 1 x 10^{-8}/hr = pump rupture rate (JRB)

COMMENTS:

- These are very low probability events producing spills which will probably be contained by an above-ground pad. These events are therefore not included in our model.

HAZARDOUS WASTE TANKS

LABEL: A1115

FAILURE: Loose flexible hose connection during pump-out (storage or accumulation tanks only).

SOURCES:

- Nuclear Regulatory Commission, Reactor Safety Study (1975)

CALCULATIONS:

- 1×10^{-2}/demand = general rate of human error (Reactor Safety Study)
- 1×10^{-2}/demand = $m \times 10^{-2}$/month where m is the number of pump-outs per month (m will generally be less than 1).

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY:

- 1×10^{-2}/demand = $m \times 10^{-2}$/month where m is the number of pump-outs per year.

VOLUME:

- Assume that the maximum loss rate is the hose flow rate. So leak rate is FNU(0, hose flow rate).

USER INPUTS:

- Number of pump-outs/year (m)
- Tank capacity (Q)

HAZARDOUS WASTE TANKS

LABEL: A2113, A2114

FAILURE: Strainer or pump rupture during tank filling.

SOURCES:

- U.S. Coast Guard (1978)
- JRB Associates (1982)

CALCULATIONS:

- 1×10^{-8}/hr = strainer rupture rate
- 1×10^{-8}/hr = pump rupture rate

COMMENTS:

- These are very low probability events producing spills which will probably be contained by an above-ground pad. These events are therefore not included in the computer model.

LABEL: A2116

EVENT: Pump Corrodes

ASSUMPTIONS:

- Pump corrosion is composed of:
  - generalized interior corrosion
  - localized interior corrosion
  - generalized exterior corrosion
  - localized exterior corrosion
  - erosion

CALCULATIONS:

- Our pump-corrosion model is very similar to our pipe-corrosion model.

- Localized interior corrosion. We model localized interior corrosion in the same way for pumps and pipes. Because a pump's complex shape makes it more vulnerable to localized interior corrosion than is a pipe, we use the same probability distributions for localized interior corrosion of pumps and pipes. See event B13, above.

- Generalized interior corrosion. Generalized interior corrosion is also the same for pumps and pipes.

- Generalized exterior corrosion. Because pumps are exposed to the atmosphere, we use a generalized exterior corrosion rate of 1.4 mils per year.

- Localized exterior corrosion. Because of the pump's small surface area and above-ground setting, localized exterior corrosion is highly unlikely and we have not included it in our pump-corrosion model.

- Erosion. Because of the pump's complex shape, it will be more subject to erosion than is a pipe. We assume the following dependence of erosion rate on fraction of suspended solids:

Fraction of Suspended Solids (ppm)	Erosion rate (mils per year)
0-10,000	FNU(0,10)
10,000	FNU(10,20)

VOLUME:

- We use the same hole sizes for pumps as we used for pipes.

COMMENTS:

- In some cases, pumps may be located inside the tank. In these cases, pump corrosion cannot produce a release of fluid.

LABEL: A210

FAILURE: Fluid flows over the top of an open-topped tank during overfill events.

ASSUMPTIONS:

- Open-topped tanks have a ready overflow route over the top of the tank.

VOLUME:

- The leak rate will be equal to the rate at which fluid is pumped into the system.
- The overflow may be detected and remedied immediately, or it may continue through the entire batch.
- We assume that the overflow duration is uniformly distributed between zero and the entire fill time for the tank. Thus, the overflow volume is given by FNU(0, volume of entire batch).

HAZARDOUS WASTE TANKS

LABEL: A211

FAILURE: Fluid flows out the vent of an above-ground tank during overfill events.

ASSUMPTIONS:

- Above-ground tanks have a ready overflow route through their vents.

VOLUME:

- The leak rate will be equal to the rate at which fluid is pumped into the system.
- The overflow may be detected and remedied immediately, or it may continue through the entire batch.
- We assume that the overflow duration is uniformly distributed between zero and the entire fill time for the tank. Thus, the overflow volume is given by FNU(0, volume of entire batch).

LABEL: A213

EVENT: Pump-out pipe rupture leads to loss during overfill events.

SOURCES: B11

PROBABILITY DISTRIBUTION:

- Non-stochastic. This event will occur if the pump-out pipe has ruptured under event B11.

PROBABILITY: See event B11 (pipe rupture)

VOLUME:

- If there is a pump, we assume that it shuts off automatically. Then, the pressure at the point of the rupture will be determined by the static hydraulic head of the backed-up fluid.
- We assume that the average rupture occurs at the midpoint of the pump-out pipe. Then the hydraulic head can be determined from the system layout.
- We assume an overfill detection/response time of FNU(.25,60) minutes (the operator notices that the fluid is not flowing).

USER INPUTS:

- System design

COMMENTS:

- This event is only important for systems for which pump-out is by flexible hose. For these tanks, this event is the only source of loss through a ruptured pump-out pipe. For other tanks, losses by this mechanism will be overshadowed by losses through the same holes during normal discharge operations.

LABEL: A214

FAILURE: Pump-out pipe corrosion results in leak during overfill events.

SOURCES: B13

PROBABILITY DISTRIBUTION:

- Non-stochastic. This event will occur if the pump-out pipe has corroded under event B13.

PROBABILITY: See event B13 (pipe corrosion)

VOLUME:

- If there is a pump, we assume that it shuts off automatically. Then, the pressure at the corrosion hole will be determined by the static hydraulic head of the backed-up fluid.
- As in event B13, we assume that the average corrosion hole occurs at the midpoint of the pump-out pipe. Then the hydraulic head can be determined from the system layout.
- We assume an overfill detection/response time of FNU(.25,60) minutes (the operator notices that the fluid is not flowing).

USER INPUTS:

- System design

COMMENTS:

- This event is only important for systems for which pump-out is by flexible hose. For these tanks, this event is the only source of loss through a corroded pump-out pipe. For other tanks, losses by this mechanism will be overshadowed by losses through the same holes during normal discharge operations.

LABEL: A215

FAILURE: Outlet flange or gasket leak produces losses during overfill events.

SOURCES: See B121 or B122

PROBABILITY DISTRIBUTION:

- Non-stochastic. This event will occur if the flange or gasket is leaking under events B121 or B122.

PROBABILITY: See event B121 (flange leak) or B122 (gasket leak).

VOLUME:

- If there is a pump, we assume that it shuts off automatically. Then, the pressure at the point of the rupture will be determined by the static hydraulic head of the backed-up fluid. This will be determined by the system design.
- We assume an overfill detection/response time of FNU(.25,60) minutes (the operator notices that the fluid is not flowing).

USER INPUTS:

- System design

COMMENTS:

- This event is only important for systems for which pump-out is by flexible hose. For these tanks, this event is the only source of loss through a leaking outlet flange or gasket. For other tanks, losses by this mechanism will be overshadowed by losses through the same hole during normal discharge operations.

LABEL: A216

FAILURE: Inlet pipe rupture produces leaks during overfill events.

PROBABILITY DISTRIBUTION:

- Non-stochastic. This event will only occur if the inlet pipe has already ruptured under event B11.

PROBABILITY: See event B11 (pipe rupture).

VOLUME:

- The leak-rate calculations are similar to those used for event A213 (pump-out pipe rupture).

COMMENTS:

- Leakage from this pipe will also produce losses during normal filling. Cumulative losses from that mechanism will generally be much larger than losses occurring during overfill events.

LABEL: A217

FAILURE: Fill pipe corrosion produces losses during overflow events.

PROBABILITY DISTRIBUTION:

- Non-stochastic. This event will only occur if the fill pipe is already corroded leaking under event B13.

PROBABILITY: See event B13 (pipe corrosion).

VOLUME:

- The leak rate can be obtained from the geometry of event B13, using a static hydraulic head. The size of the corrosion hole is determined under event B13.

COMMENTS:

- Leakage from this hole will also produce losses during normal filling. Cumulative losses from that mechanism will generally be much larger than losses occurring during overfill events.

LABEL: A218

FAILURE: Inlet flange or gasket leaks during overfill events.

PROBABILITY DISTRIBUTION:

- Non-stochastic. This event will only occur if the inlet flange or gasket is already leaking under events B121 or B122.

PROBABILITY: See event B121 (flange leak) or B122 (gasket leak).

VOLUME:

- The leakage calculations are identical to those used for event A215 (outlet flange or gasket leak).

COMMENTS:

- Leakage from this flange or gasket will also produce losses during normal filling. The leak rate will be much higher during overflow, however, because the pressure will be much higher under the conditions of static hydraulic head that occur during overflow than it will be when fluid is in motion during normal filling. During normal filling, the pressure at this location is very low.

LABEL: A219

FAILURE: Vent pipe rupture produces losses during overfill events.

CALCULATIONS: See event B11 (pipe rupture).

PROBABILITY: See event B11.

VOLUME:

- The volume can be obtained from the system layout, using static hydraulic heads and sizing the rupture according to the method used for other pipe ruptures. See event B11.

LABEL: A220

FAILURE: Vent pipe corrosion produces losses during overfill events.

CALCULATIONS: See event B13 (pipe corrosion).

PROBABILITY: See event B13.

VOLUME:

- The volume can be obtained from the system layout, using static hydraulic heads and sizing the corrosion hole according to the method used for other pipe ruptures. See event B13.

LABEL: A221

FAILURE: Vent pipe flange leaks during overfill events.

CALCULATIONS: See event B121 (welded flange leaks).

PROBABILITY: See event B121.

VOLUME:

- The volume can be obtained from the system layout, using static hydraulic heads and sizing the flange leak according to the method used for other flange leaks. See event B13.

LABEL: B21

FAILURE: Asphalt Pad Breached

SOURCES: Conversations with local asphalt contractors.

ASSUMPTIONS:

- Breakage in a 2" pad with 6" class-5 base (a mixture of gravel, sand, and clay) will become general in an average of 8-12 years, depending on maintenance. It could occur as early as 3-5 years.
- A 3-4" pad with a crushed limestone base should last 15 years before generalized break-up begins.
- Break-up will occur earlier if the pad is not properly maintained.
- The entire spill volume is lost if the pad has broken up.

PROBABILITY DISTRIBUTION: Beta

PROBABILITY:

- For 2" pad, no maintenance, we use a beta distribution with a minimum value of 2.5 years, a mode of 8 years, and a maximum of 12 years.
- For a 2" pad, with maintenance, (or a 3-4" pad without maintenance) we use a beta distribution with parameters (4, 12, 15).
- For a 3-4" pad with maintenance, we use a beta distribution with parameters (5, 15, 18).

VOLUME: Entire volume of the spill.

HAZARDOUS WASTE TANKS

LABEL: B31

FAILURE: Concrete Pad Breached

SOURCES:

- Telephone conversations with concrete contractors and officials in the Minnesota Department of Transportation.

PROBABILITY DISTRIBUTION: Normal

PROBABILITY: N(30,5)

VOLUME: Entire volume of spill.

LABEL: B33

FAILURE: Breach of Concrete Berm

ASSUMPTIONS:

- Concrete berms will age similarly to concrete pads (see event B31).

SOURCES: Event B31

PROBABILITY DISTRIBUTION: Normal

Probability: N(30,5)

VOLUME: Total spill volume.

LABEL: B41

FAILURE: Concrete Vault Fails

SOURCES:

- Best engineering judgment after converstations with concrete contractors.

PROBABILITY DISTRIBUTION: Normal

PROBABILITY: N(35,10)

VOLUME: Total volume of spill.

LABEL: B51

FAILURE: Synthetic Liner Fails

SOURCES:

- EPA, Liner Location Report (1984).

PROBABILITY DISTRIBUTION: Normal

PROBABILITY: N(35,10)

VOLUME: Total volume of spill.

HAZARDOUS WASTE TANKS

LABEL: ANUCAT(I,1)

FAILURE: Vehicle Crash

ASSUMPTIONS:

- This event is included in tank or pipe rupture (events T1124 and B11).

LABEL: ANUCAT (I,2) (aboveground or in-ground tanks only)

FAILURE: Vandalism of tank system resulting in total system loss.

ASSUMPTIONS:

- We assume that the probability of catastrophic release due to vandalism is of the same order of magnitude as the probability of catastrophic release due to a vehicle crash.

SOURCES:

- SCS Engineers (1983), Figure 4-18, p. 4-29.
- JRB Associates (1982), Exhibit 3-5.

CALCULATIONS:

- $< 1 \times 10^{-10}$/hr = failure rate for vehicle crash (JRB).
- 10^{-10}/hr = $(1 \times 10^{-10}$/hr)(24 hr/day)(365 day/yr) = 10^{-6}/yr.

PROBABILITY: 1×10^{-6}/yr

PROBABILITY DISTRIBUTION: Binomial

VOLUME: Entire tank contents.

HAZARDOUS WASTE TANKS

LABEL: ANUCAT (I,3)

FAILURE: Tornado/hurricane (i.e. high wind storm event) resulting in total system loss (above-ground or in-ground tanks only).

ASSUMPTIONS:

- The facility is in coastal area subject to periodic hurricanes or in a tornado-prone area.
- The annual probability of a great hurricane (winds exceeding 125 mph) for 50-mile segments along the U. S. coastline ranges from 1% to 7% (Petak and Atkisson).
- Assume 20% damage for hurricanes with wind speeds of 125 mph (Petak and Atkisson).
- Assume an average of 2.5 tornado strikes per 10,000 square miles for the continental U.S. (U.S. Weather Bureau).
- Approximately 35% of all tornadoes have a Fujita classification of F2 or above (135 - 290 mph) (Petak and Atkisson).
- Assume approximately 50% damage for structures affected by tornadoes with a Fujita classification of F2 or above (Petak and Atkisson).
- Assume a facility has an area of approximately 10 acres.
- Assume that the average tornado strike is 2 mi x 300 yards = 200 acres. (U.S. Weather Bureau.)

SOURCES:

- Petak, William J. and Arthur A. Atkisson, Natural Hazard Risk Assessment and Public Policy: Anticipating the Unexpected, Springer-Verlag, New York (1982).
- United States Weather Bureau, Minneapolis Office, Personal Communication.

CALCULATIONS:

- 7% annual probability of hurricanes x 20% chance of damage = 1.4% chance of a damage due to a hurricane.

- (2.5/10,000) tornado strikes per square mile x (200 acres/strike) x ($1 mi^2$/640 acres) x 10 acres/facility x (.35 x .5) probability of damage = 1.5×10^{-4}/yr per facility.

PROBABILITY:

- 0.014/yr for hurricanes
- 1.5×10^{-4}/yr for tornadoes

PROBABILITY DISTRIBUTION: Binomial

VOLUME: Entire tank contents

USER INPUTS:

- Is facility in a tornado zone?
- Is facility in a hurricane zone?

COMMENTS: This event only applies for above-ground or in-ground facilities.

LABEL: ANUCAT (I,4)

FAILURE: Earthquake causes total system loss.

ASSUMPTIONS:

- The facility is located in a seismically active area. Recurrence intervals for damaging earthquakes in Los Angeles and San Francisco areas are between 100 and 125 years.
- Assume .5 - 15% damage to commercial structures (built in California after 1933) in response to an earthquake with intensity of 7 or above.

SOURCES:

- California Institute of Technology (personal communication).

CALCULATIONS:

- (1/125) earthquakes per year x 10% average probability of damage $= 8 \times 10^{-4}$ damaging earthquakes per year.

PROBABILITY: .0008/yr

PROBABILITY DISTRIBUTIONS: Binomial

VOLUME: Entire tank contents

USER INPUTS:

- Is facility in a seismically active area?

LABEL: ANUCAT (I,5)

FAILURE: Flood causes total system loss (above- or in-ground tanks only).

ASSUMPTIONS:

- The facility is located in a flood prone area.
- The facility is designed to withstand up to a 100-year flood.

SOURCES:

- Thomas Dunne and Luna Leopold, Water in Environmental Planning, W. H. Freeman and Company, San Francisco (1978).
- William J. Petak and Arthur A. Atkisson, Natural Hazard Risk Assessment and Public Policy: Anticipating the Unexpected, Springer-Verlag, New York (1982).

CALCULATIONS:

- According to Petak and Atkisson there is a 50% chance that a flood will result in damage to an above-ground tank.
- There is a 1% chance per year of a 100-year flood.
- 1% x 50% = .5%

PROBABILITY: .005/yr

PROBABILITY DISTRIBUTION: Binomial

VOLUME: Entire contents of tank.

USER INPUT:

Is facility located in a flood-prone area?

COMMENTS: This event applies only for above- or in-ground facilities.

LABEL: ANUCAT (I,6)

FAILURE: Ignition source available to ignite waste in tank system (all systems).

ASSUMPTIONS:

- The tank is properly grounded.
- The operator is reasonably cautious in handling the waste.

PROBABILITY: 1 x 10^{-6}/yr

PROBABILITY DISTRIBUTION: Binomial

VOLUME: Entire tank contents

COMMENTS:

- This event applies if the waste itself is the source of the fire. If the tank is ruptured by a nearby fire or explosion, ANUCAT (I,7) applies.
- This event applies only if the waste is flammable.

HAZARDOUS WASTE TANKS

LABEL: ANUCAT (I,7)

FAILURE: Nearby fire or explosion causes complete system loss.

ASSUMPTIONS:

- A nearby fire or explosion is 1/3 as likely to damage an underground tank as it is to damage an above-ground tank.

SOURCES:

- JRB Associates (1982), Exhibit 3-5

CALCULATIONS:

- 3×10^{-7}/hr - probability of nearby fire (JRB)
- $(3 \times 10^{-7}/\text{hr})(24\ \text{hr/day})(365\ \text{days/yr}) = 2.6 \times 10^{-3}/\text{yr}$

PROBABILITY:

- 3×10^{-3}/yr (above-ground or in-ground) tank
- 1×10^{-3}/yr (below-ground tank)

PROBABILITY DISTRIBUTION: Binomial

VOLUME: Entire tank contents

LABEL: LIFDEF (I,1) and LIFDEF (I,2)

FAILURE: Vibrational/tortional stress causes rupture due to inadequate support or due to a construction defect.

ASSUMPTIONS:

- The only part of the system subject to vibration is the pump.
- We assume that these losses are included in pipe rupture (event B11).

PROBABILITY: Zero. This loss mechanism is included in event A1113.

LABEL: LIFDEF (I,3)

FAILURE: Inspection fails to detect installation damage or fabrication errors.

ASSUMPTIONS:

- Assume four levels of inspection/testing:
  1) none
  2) low--visual inspection
  3) medium--visual inspection and weld testing
  4) high--visual inspection, weld testing, and tightness testing

SOURCES:

- Best engineering judgment based on human error probabilities listed in Nuclear Regulatory Commission, Reactor Safety Study (1975)

PROBABILITY (by inspection level):

None	- 1.00
Low	- 0.50
Medium	- 0.25
High	- 0.05

PROBABILITY DISTRIBUTION: Binomial

USER INPUTS:

- Level of inspection or testing.

LABEL: LIFDEF (I,4)

FAILURE: Off-spec materials used in construction.

ASSUMPTIONS:

- Use of poor-grade materials would accelerate the onset of various leaks and ruptures. Since our probability distributions for these events are based on empirical data (the API/SCS survey) we assume that these probability distributions already account for off-spec materials.

LABEL: LIFDEF (I,5)A

FAILURE: Tank damaged during installation.

SOURCES:

- Best engineering judgment

PROBABILITY: 2×10^{-2}

PROBABILITY DISTRIBUTION: Binomial

VOLUME:

- We assume that the damage is similar to a seam leak.
- The volume will therefore be identical to volume loss from seam leaks (see event T1124). Leakage will begin in year 1.

VARIATIONS:

- Concrete and Stainless Steel Tanks. Since steel and stainless steel are approximately the same strength, we assume that stainless steel is just as vulnerable to installation damage as is steel. Based on conversations with concrete contractors, we assume that concrete also has a 2% chance of cracking due to improper installation.
- Fiberglass tanks. Fiberglass tanks are twice as likely to rupture as are steel tanks (see event T1124). We therefore assume that they are also twice as vulnerable to installation damage.

COMMENTS:

- Due to a transcription error, we used a value of .03 for the installation damage probability for steel, stainless steel, and concrete. This error did not substantially alter our results. It will be corrected in subsequent versions of the model.

LABEL: LIFDEF (I,5)B

FAILURE: Underground piping damaged during installation.

SOURCES: Best engineering judgment

PROBABILITY: 1×10^{-2}

PROBABILITY DISTRIBUTION: Binomial

VOLUME:

- We assume that the damage is similar to that from a pipe rupture.
- The leak rate will therefore be identical to that from event B11. Loss will begin in year 1.

VARIATIONS:

- Stainless steel pipes. Since steel and stainless steel are approximately the same strength, we assume that they are equally vulnerable to installation damage.
- Fiberglass pipes. Fiberglass is twice as likely to rupture as is steel (see event T1124). We therefore assume that fiberglass pipes have an installation-damage probability of 2×10^{-2}.

LABEL: LIFDEF (I,5)C

FAILURE: Above-ground piping damaged during installation.

SOURCES: Best engineering judgment

PROBABILITY: 1×10^{-2}

PROBABILITY DISTRIBUTION: Binomial

VOLUME:

- The leak rate is the same as that from an above-ground pipe rupture (see event B11).
- Leakage will begin in year 1.

VARIATIONS:

- Stainless steel pipes. Since steel and stainless steel are approximately the same strength, we assume that they are equally vulnerable to installation damage.
- Fiberglass pipes. Fiberglass is twice as likely to rupture as is steel (see event T1124). We therefore assuem that fiberglass pipes have an installation-damage probability of 2×10^{-2}.

HAZARDOUS WASTE TANKS

LABEL: LIFDEF (I,5)D

FAILURE: Welded flange damaged during installation.

SOURCES:

- Best engineering judgment

PROBABILITY: 2×10^{-2}

PROBABILITY DISTRIBUTION: Binomial

VOLUME:

- We assume that the leak rate is the same as that for a welded flange leak (event B121).
- Leakage will begin in year 1.

LABEL: LIFDEF (I,5)E

FAILURE: Gasket damaged during installation (or improperly installed).

SOURCES:

- Best engineering judgment

PROBABILITY: 1.5×10^{-2}

PROBABILITY DISTRIBUTION: Binomial

VOLUME:

- We assume that the leak rate is the same as that for a gasket failure (event B122).
- Leakage begins in year 1.

HAZARDOUS WASTE TANKS

LABEL: LIFDEF (I,6) and (I,7)

FAILURE: Stresses due to settling.

ASSUMPTIONS: This event is already included in tank and piping ruptures.

LABEL: FLVCN1

FAILURE: Automatic level controller fails.

ASSUMPTIONS:

- Assume that the failure of the controller, the controller settings, and the impulse lines may each cause controller malfunction

SOURCES:

- Anyakora, Engel and Lees, Table V, p. 400

CALCULATIONS:

- 0.29/yr = 7.9×10^{-4}/dy = controller failure rate (Anyakora, Engel and Lees).
- 0.14/yr = 3.8×10^{-4}/dy = controller settings failure rate (Anyakora, Engel and Lees).
- 0.77/yr = 2.1×10^{-3}/dy = impulse lines failure rate (Anyakora, Engel and Lees).
- $7.9 \times 10^{-4} + 3.8 \times 10^{-4} + 2.1 \times 10^{-3} = 3.3 \times 10^{-3}$/dy
- 3.3×10^{-3}/dy = 9.4×10^{-2}/mo

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: 9.4×10^{-2}/mo

LABEL: FLVCN2

FAILURE: Emergency shut-off level controller fails to function.

ASSUMPTIONS:

- We assume that the emergency shut-off controller is inspected monthly.

SOURCES: See event FLVCN1

CALCULATIONS:

- According to event FLVCN1, the probability of automatic level controller failure is 9.4×10^{-2}/mo.
- If the level controller is inspected monthly, then the average failure lasts half a month. The probability that the controller is in a failed state at any given time is therefore $.5 \times 9.4 \times 10^{-2}$, which is approximately 5×10^{-2}.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: .05/Demand

LABEL: LEVIN2

FAILURE: Emergency shut-off level sensor fails to function.

ASSUMPTIONS:

- We assume that the published failure rates include failures in the meter, the sensor, and the impulse lines.
- We assume that the emergency shut-off level sensor is inspected monthly.

SOURCES:

- Anyakora, Engel, and Lees (1971), Table V, p. 400.

CALCULATIONS:

- .2/yr = failure rate for a capacitance-type level transducer (Anyakora, Engel and Lees).
- .2/yr = 5.5×10^{-4}/day = 1.6×10^{-2}/mo.
- If the level controller is inspected monthly, then the average failure lasts half a month. The probability that the controller is in a failed state at any given time is therefore $.5 \times 1.6 \times 10^{-2}$, which is 8×10^{-3}.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: 8×10^{-3}

COMMENTS:

- Due to a transcription error, this event's probability was set to the probability calculated for event FLVCN2. The result was a conservative error but the number will be changed to the value calculated above in future versions of the model.

LABEL: MOALARM

FAILURE: High liquid level alarm system failure.

ASSUMPTIONS:

- We assume that the high level alarm is tested once per year. Thus, the average alarm failure will persist for 6 months.

SOURCES:

- Lawley (1974), p. 54, note 6.

CALCULATIONS:

- 0.2/yr = frequency of dangerous high level alarm failures (Lawley).
- 6 months = duration of average undetected failure.
- 0.2 (6/12) = 0.1 = fractional dead time for high level alarm.

PROBABILITY: .1/demand

PROBABILITY DISTRIBUTION: Binomial

COMMENTS:

- The same failure probability applies to leak detectors in vaulted tanks or interstitial alarms in double-walled tanks or pipes.
- We also model interstitial alarms according to this probability distribution. Many of these alarms, however, have status lights which can be checked at any desired frequency. Thus, if status is checked conscientiously, the per-demand failure probability may be considerably lower. Our value of 10% is therefore a conservative estimate.

HAZARDOUS WASTE TANKS

LABEL: MOFILL

FAILURE: Tank is to be filled nearly to capacity.

ASSUMPTIONS:

- Treatment tanks are always filled to their operating capacities.
- We assume that pump-out schedules for storage or accumulation tanks generally allow sufficient margin for error that the tank is not filled completely to capacity unless something interferes with the normal pump-out schedule or there is an unexpected upsurge in the generation of waste. We conservatively assume that this happens once per year.

CALCULATIONS:

- 1 per year = .0027 per day = $1 - (1-.0027)^{30}$ = .079 per month.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY:

- 1.00 for treatment tanks.
- .079/mo. for storage or accumulation tanks.

LABEL: MOLEVIN

FAILURE: Level indicator malfunction results in attempted overfill.

ASSUMPTIONS:

- We assume that the published failure rates include failures in the meter, the sensor, and the impulse lines.
- We assume that a fault is detected and repaired after one faulty transfer.

SOURCES:

- Anyakora, Engel, and Lees (1971), Table V, p. 400.

CALCULATIONS:

- .22/yr = failure rate for a capacitance-type level transducer (Anyakara, Engel, and Lees).
- .22 x .5 = .1/yr = rate of overfill events due to level transducer failure.
- $.2/\text{yr} = 5.5 \times 10^{-4}/\text{day} = 1-(1-5.5 \times 10^{-4})^{30}/\text{mo}$.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: .16/mo.

VOLUME:

- Assume that the overflow consists of between 0 and 100% of a batch. Thus Q = FNU(0, volume of one batch).

USER INPUTS:

- Volume transferred per batch

COMMENT:

- Due to a round-off error our model uses a probability of .15/mo. The difference between this and the correct value is not significant.

LABEL: MOPMCE

FAILURE: Outlet pump fails to start on demand (extreme environment)

ASSUMPTIONS:

- 75% of pump failures are failures to start. The remaining 25% are failures to run under event MOPMOE

SOURCES:

- Nuclear Regulatory Commission, Reactor Safety Study (1975), Table III 2-3.
- Southwest Research Institute (1982).
- Henley and Kumamoto (1981), Figure 6.7, p. 278.

CALCULATIONS:

- 1×10^{-4} to 1×10^{-3} per operating hour = probability of pump failure in extreme environment (Reactor Safety Study)
- The geometric mean of this range of values = 3×10^{-4} per operating hour.
- $(3 \times 10^{-4}/\text{hr})(.75) = 2.25 \times 10^{-4}$ per operating hour = probability that pump fails to run.
- We convert this per-hour probability into a per-demand probability. We do this by noting that the pump must have started properly when the previous batch drained. Otherwise, the operator would have noticed the failure and repaired it. Thus, if the pump fails, it does so during the fill time for the present batch. The probability of this is given by:

$$(2 \times 10^{-4} \times \text{fill time})$$

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: $(2 \times 10^{-4} \times$ fill time per batch) per demand.

USER INPUTS:

- The per-batch fill time

COMMENTS:

- For continuous systems, the fill time is the entire operating day.
- Due to a round-off error our model uses a probability of $3 \times 10^{-4} \times$ fill time per batch. The difference between this and the correct value is not significant.

HAZARDOUS WASTE TANKS

LABEL: MOPMCN

FAILURE: Outlet pump fails to start on demand (normal environment)

ASSUMPTIONS:

- 75% of pump failures are failure to start. The remaining 25% are failures to run under event MOPMON.

SOURCES:

- Nuclear Regulatory Commission, Reactor Safety Study (1975), Table III 2-3.
- Southwest Research Institute (1982).
- Henley and Kumamato (1981), Figure 6.7, p. 278.

CALCULATIONS:

- 1×10^{-6} to 1×10^{-5} per operating hour = probability of pump failure in normal environment (Reactor Safety Study).
- The geometric mean of this range of values = 3×10^{-6} per operating hour.
- $(3 \times 10^{-6}/\text{hr})(.75) = 2.25 \times 10^{-6}$ per operating hour = probability that pump fails to run.
- We convert this per-hour probability into a per-demand probability. We do this by noting that the pump must have started properly when the previous batch drained. Otherwise, the operator would have noticed the failure and repaired it. Thus, if the pump fails, it does so during the fill time for the present batch. The probability of this is given by:

$$(2 \times 10^{-6} \times \text{fill time})$$

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: $(2 \times 10^{-6} \times$ fill time per batch) per demand.

USER INPUTS:

- The per-batch fill time

COMMENTS:

- For continuous systems, the fill time is the entire operating day.
- Due to a round-off error our model uses a probability of 3×10^{-6} x fill time per batch. The difference between this and the correct value is not significant.

HAZARDOUS WASTE TANKS

LABEL: MOPMOE

FAILURE: Pump fails in "on" position, preventing emergency shut-off (extreme environment).

ASSUMPTIONS:

- Assume that failure of the solenoid or the controller can cause a pump to fail in the open position. We assume that these subcomponent failures make up approximately 25% of all pump malfunctions.

SOURCES:

- Nuclear Regulatory Commission, Reactor Safety Study (1975).
- Southwest Research Institute (1982).
- Henley and Kumamoto (1981), Figure 6.7, p. 278.

CALCULATIONS:

- 1×10^{-4} to 1×10^{-3} per operating hour = probability of pump failure in extreme environment (Reactor Safety Study).
- The geometric mean of this range of values = 3×10^{-4} per operating hour.
- $(3 \times 10^{-4}/\text{hr})\ (.25) = 7.5 \times 10^{-5}$ per operating hour = probability that the pump fails in the "on" position.
- We need to convert this per-hour probability into a per-demand probability. We do this by noting that the pump must have shut off properly after the previous batch finished filling. Otherwise, the operator would have noticed the failure and repaired it. Thus, if the pump fails it does so during the fill time for the present batch. The probability of this is given by:

$$(7.5 \times 10^{-5} \times \text{fill time})$$

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: $(7.5 \times 10^{-5}$ x fill time per batch) per demand

USER INPUTS:

- The per-batch fill time

COMMENTS:

- For continuous systems, the fill time is the entire operating day.

LABEL: MOPMON

FAILURE: Pump fails in "on" position, preventing emergency shut-off (normal environment).

ASSUMPTIONS:

- Assume that failure of the solenoid or the controller can cause a pump to fail in the open position. We assume that these subcomponent failures make up approximately 25% of all pump malfunctions.

SOURCES:

- Nuclear Regulatory Commission, Reactor Safety Study (1975).
- Southwest Research Institute (1982).
- Henley and Komamoto (1981), Figure 6.7, p. 278.

CALCULATIONS:

- 1×10^{-7} to 1×10^{-4} per operating hour = probability of pump failure in normal environment (Reactor Safety Study).
- The geometric mean of this range of values = 3×10^{-6} per operating hour.
- $(3 \times 10^{-6}/\text{hr})(.25) = 7.5 \times 10^{-7}$ per operating hour = probability that the pump fails in the "on" position.
- We convert this per-hour probability into a per-demand probability in the same way that we do for pumps in an extreme environment (event MOPMOE). Thus, the probability is given by:

$$(7.5 \times 10^{-7} \times \text{fill time})$$

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: (7.5×10^{-7} x fill time per batch) per demand

USER INPUTS:

- The per-batch fill time

COMMENTS:

- For continuous system, the fill time is the entire operating day.

HAZARDOUS WASTE TANKS

LABEL: MOVLCE

FAILURE: Outlet valve fails in the closed position, preventing emergency shut-off (extreme environment).

ASSUMPTIONS:

- We assume that 50% of valve failures occur in the closed position.

SOURCES:

- Anyakora, Engel, and Lees (1971), Table V.
- Southwest Research Institute (1982), Table 2, p. 32.
- Henley and Kumamoto (1981), Figure 6.7, p. 278.
- Nuclear Regulatory Commission, Reactor Safety Study, (1975), Table III-2-3.

CALCULATIONS:

- 0.60/yr = expected number of control valve failures in a normal environment. (Anyakora, Engel and Lees (1971).
- Valve failures are 10 times more common in extreme than normal environments. (Source, best engineering judgment based on Henley and Kumamoto (1981) and Reactor Safety Study). Therefore, 6.0/yr = the expected number of control valve failures in an extreme environment.
- If 50% of these failures occur in the closed position, then 3.0/yr = the expected number of control valves failing in the closed position.
- 3.0/yr = 3.4×10^{-4}/hr
- Since the valve must have been functional at the time the previous batch drained, this event can only occur if failure occurs during the time when the tank is being filled. Thus, the per demand failure probability is given by:

$$(3.4 \times 10^{-4}) \times (\text{fill time per batch})$$

PROBABILITY DISTRIBUTION: Binomial (per demand)

PROBABILITY: $(3.4 \times 10^{-4}) \times$ (fill time per batch) per demand

USER INPUTS:

- Fill time per batch
- Number of operating hours per day

COMMENTS:

- For continuous systems, the fill time is the entire operating day.

HAZARDOUS WASTE TANKS

LABEL: MOVLCN

FAILURE: Outlet valve fails in the closed position, preventing emergency shutoff (normal environment).

ASSUMPTIONS:

- Failures are only 10% as likely in normal as extreme environments (see sources cited under event MOVLCE).

SOURCES: See event MOVLCE

CALCULATIONS:

- The per demand probability of failure in an extreme environment is 3.4×10^{-4} x (fill time per batch). See event MOVLCE.

PROBABILITY DISTRIBUTION: Binomial (per demand)

PROBABILITY: (3.4×10^{-4}) x (fill time per batch)

USER INPUTS:

- Fill time per batch
- Number of operating hours per day

COMMENTS:

- For continuous systems, the fill time is the entire operating day.

LABEL: MOVLOE

FAILURE: Inlet valve fails in the open position, preventing emergency shut-off (extreme environment).

ASSUMPTIONS:

- Assume that 50% of valve failures occur in the open position.

SOURCES:

- Anyakora, Engel, and Lees (1971), Table V.
- Southwest Research Institute (1982), Table 2, p. 32.
- Henley and Kumamoto (1981), Figure 6.7, p. 278.
- Nuclear Regulatory Commission, Reactor Safety Study (1975) Table III-2-3.

CALCULATIONS:

- 0.60/yr = expected number of control valve failures in a normal environment (Anyakora, Engel and Lees (1971)).
- Valve failures are 10 times more common in extreme than normal environments. (Source, best engineering judgment based on Henley and Kumamoto (1981) and Reactor Safety Study). Therefore, 6.0/yr = the expected number of control valve failures in an extreme environment.
- If 50% of these failures occur in the open position, then 3.0/yr = the expected number of control valves failing in the open position.
- 3.0/yr = 3.4×10^{-4}/hr.
- Since the valve must have been functional at the time the batch began to fill, this event can only occur if failure occurs during the time when the tank is being filled. Thus, the per demand failure probability is (3.4×10^{-4}) x (fill time per batch).

PROBABILITY DISTRIBUTION: Binomial (per demand)

PROBABILITY: (3.4×10^{-4}) x (fill time per batch)

USER INPUTS:

- Fill time per batch
- Number of operating hours per day

COMMENTS:

- For continuous systems, the fill time is the entire operating day.
- This event can also cause an attempted overfill. We only model this form of attempted overfill for gravity-fed systems, however, because for pump-fed systems, the failure can be remedied by shutting off the pump. In theory, the pump could also fail in the "on" position, causing an attempted overfill even for pump-fed systems, but such simultaneous failure is extremely unlikely, and is overshadowed by the other types of failure (e.g. operator error) which are more likely to cause attempted overflows.

LABEL: MOVLON

FAILURE: Inlet valve fails in the open position, preventing emergency shut-off (normal environment).

ASSUMPTIONS:

- Failures are only 10% as likely in normal as extreme environments (see sources cited under event MOVLOE).

SOURCES: See event MOVLOE

CALCULATIONS:

- The per demand probability of failure in an extreme environment is (3.4×10^{-4}) x (fill time per batch). See event MOVLOE.

PROBABILITY DISTRIBUTION: Binomial (per demand)

PROBABILITY: (3.4×10^{-5}) x (fill time per batch)

USER INPUTS:

- Fill time per batch
- Number of operating hours per day

COMMENTS:

- For continuous systems, the fill time is the entire operating day.
- This event can also cause an attempted overfill. We only model this form of attempted overfill for gravity-fed systems, however, because for pump-fed systems, the failure can be remedied by shutting off the pump. In theory, the pump could also fail in the "on" position, causing an attempted overfill even for pump-fed systems, but such simultaneous failure is extremely unlikely, and is overshadowed by the other types of failure (e.g. operator error) which are more likely to cause attempted overflows.

LABEL: OFTROM

FAILURE: Operator fails to respond to high level alarm.

ASSUMPTIONS:

- Failure may be due to failure to hear alarm, failure to take corrective action, or inability to take corrective action.

SOURCES:

- Lawley (1974), p. 54, note 7.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: 3×10^{-2}/demand

HAZARDOUS WASTE TANKS

LABEL: OFTRCOM

FAILURE: Operator erroneously responds to high level alarm.

ASSUMPTIONS:

- At the time when the alarm first sounds, the operator feels no sense of panic. He responds in a routine manner.

SOURCES:

- Nuclear Regulatory Commission, Reactor Safety Study (1975).

CALCULATIONS:

- 3×10^{-3}/demand = probability of human error of commission (selecting wrong switch, etc.), Reactor Safety Study, Table III 6-1.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: 3×10^{-3}/demand

COMMENTS:

- If the operator panics, the probability of error will be much higher. The Reactor Safety Study gives an error rate of 20-30% for trained personnel under high stress levels where dangerous activities are occurring rapidly.

LABEL: OPCOMM

FAILURE: Operator error in batch start-up leads to attempted overfill.

ASSUMPTIONS:

- Operate action is required to initiate the transfer of fluid at the start of each batch. Mistakes may result in an attempt to transfer too much fluid.
- Operator action is also necessary whenever a continuous process is started up. We assume that this occurs once per operating day.

SOURCES:

- Nuclear Regulatory Commission (1975)

CALCULATIONS:

- 3×10^{-3}/demand = estimated rate of human errors of commission (e.g. selecting a wrong switch). Source: Nuclear Regulatory Commission.
- Let n be the number of batches per day. (Let n = 1 for continuous systems).
- Then the probability that the operator makes no errors is $1-3 \times 10^{-3}$ per batch, or

  $$(1-.003)^{30n}$$

  per month. The probability of 1 or more errors is

  $$1-(1-.003)^{30n}$$

  per month.
- If n = 1 this value is .086/mo.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY:

- $1 - .997^{30n}$/mo for batch systems

- .086/mo for continuous systems

USER INPUTS:

- Number of batches per day (n)

HAZARDOUS WASTE TANKS

LABEL: OPVLOE

FAILURE: Inlet valve fails to close, causing overflow (extreme/environment).

ASSUMPTIONS:

- This event only applies for automatic valves. Manual valves are very unlikely to fail since they have no automated components.

SOURCES: See event MOVLOE.

CALCULATIONS:

- According to event MOVLOE, the probability of such an event is 3.4×10^{-4}/hr.

- The probability of failure during any given batch is therefore $(T_b)(3.4 \times 10^{-4})$ where T_b is the fill time per batch.

- The probability of failure during any given month is

  $$1-\left[1-T_b(3.4 \times 10^{-4})\right]^{n_b m}$$

  where n_b is the number of batches per day, and m is the number of operating days per month. For continuous systems, n_b is 1 and T_b is the entire operating day.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: $1-\left[1 - T_b(3.4 \times 10^{-4})\right]^{n_b m}$

USER INPUTS:

- Fill-time per batch (T_b)
- Number of batches per day (n_b)
- Number of operating day per month (m)

HAZARDOUS WASTE TANKS

LABEL: OPVLON

FAILURE: Inlet valve fails to close, causing overflow (normal environment)

ASSUMPTIONS:

- This event only applies for automatic valves. Manual valves are very unlikely to fail since they have no automated components.

SOURCES: See event MOVLON

CALCULATIONS:

- According to event MOVLON, the probability of such an event is 3.4×10^{-5}/hr.

- The probability of failure during any given failure is therefore $(T_b)(3.4 \times 10^{-5})$ where T_b is the fill time per batch.

- The probability of failure during any given month is

$$1- \left[1-T_b(3.4 \times 10^{-4})\right]^{n_b m}$$

where n_b is the number of batches per day, and m is the number of operating days per month. For continuous systems, n_b is 1 and T_b is the entire operating day.

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: $1- \left[1-T_b(3.4 \times 10^{-5})\right]^{n_b m}$

USER INPUTS:

- Fill-time per batch (T_b)
- Number of batches per day (n_b)
- Number of operating days per month (m)

HAZARDOUS WASTE TANKS

LABEL: PADINSF, VLTINSF, CRBINSF

FAILURE: Visual inspection fails to detect secondary containment failure (pad, vault, curb)

ASSUMPTIONS:

- We assume that this visual inspection is a passive "walk-around."
- We assume that the visual inspection is infrequent enough that it does not become monotonously routine to the operator.

SOURCES:

- Best engineering judgment based on Nuclear Regulatory Commission, Reactor Safety Study (1975), and Lawley (1974).

PROBABILITY DISTRIBUTION: Binomial

PROBABILITY: .1

COMMENTS:

- For simplicity, we assume that all secondary-containment failures occur at the beginning of the month and that they are repaired immediately after detection. Thus, the secondary-containment system is in a failed state for a minimum of one complete month. A similar result would be obtained by assuming that cracks occur in the middle of the inspection cycle, and that repair takes two weeks.
- We assume that all secondary-containment inspections are statistically independent events. Thus a failure to detect a breach in a vault does not influence the probability that the inspector will also fail to detect a breach in a pad or curb. Similarly, a failure to detect a fault in one month does not change the probability that it will be detected during the next inspection.

APPENDIX B

Statistical Analysis of PACE Tank Corrosion Data

INTRODUCTION

A group of Canadian oil companies, working through the Petroleum Association for Conservation of the Canadian Environment (PACE) have compiled data on 300 underground gasoline storage tanks.[1] It is unclear what sampling techniques were used to select the 300 tanks, but it appears that the intent was to obtain a "snapshot" of the contemporary situation. It is not clear whether the data distinguishes interior and exterior corrosion, but since the intent was to determine the effect of soil variations on tank leakage, it must be assumed that the survey focused on exterior corrosion. The Canadian survey therefore represents raw data distinct from the API tank leak survey[2] and independent from either Warren Rogers'[3] preliminary or revised statistical model.

In raw form, these data are presented in Figures 1 and 2.[4] They consist of scatter diagrams of tank age and "Soil Aggressiveness Values" (SAV) for 108 leaking tanks and 192 non-leaking tanks. Each dot on the scatter diagrams represents one or more tanks, with overlapping points tallied by the small numerals adjacent to the relevant dots. Numerical listings of all 300 points are presented in Tables 1, 2, 3, and 4.

SAV is calculated according to the formula depicted in Figure 3. It is designed to incorporate soil resistivity, pH, moisture content, and sulfides, as well as the effect of variations in resistivity and pH over the tank installation site. The resultant numerical index is designed to present a cardinal ranking of soil

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[1] This data is discussed in PACE, "Underground Tank Systems: Review of State of the Art and Guidelines," PACE report No. 82-3, Ottawa (1983).

[2] American Petroleum Institute, Tank and Piping Leak Survey, 1977 to 1980.

[3] Warren Rogers Associates, Inc., "Prediction of Leaks in Unprotected Steel Storage Tanks," included in correspondence package from Betsy Tam, EPA to Chris Lough, PRA.

[4] These data were provided by Esso Petroleum, Canada. Esso Canada participated in the PACE study.

FIGURE 1

LEAKING TANK CHART

AGE VS. SOIL AGGRESSIVENESS

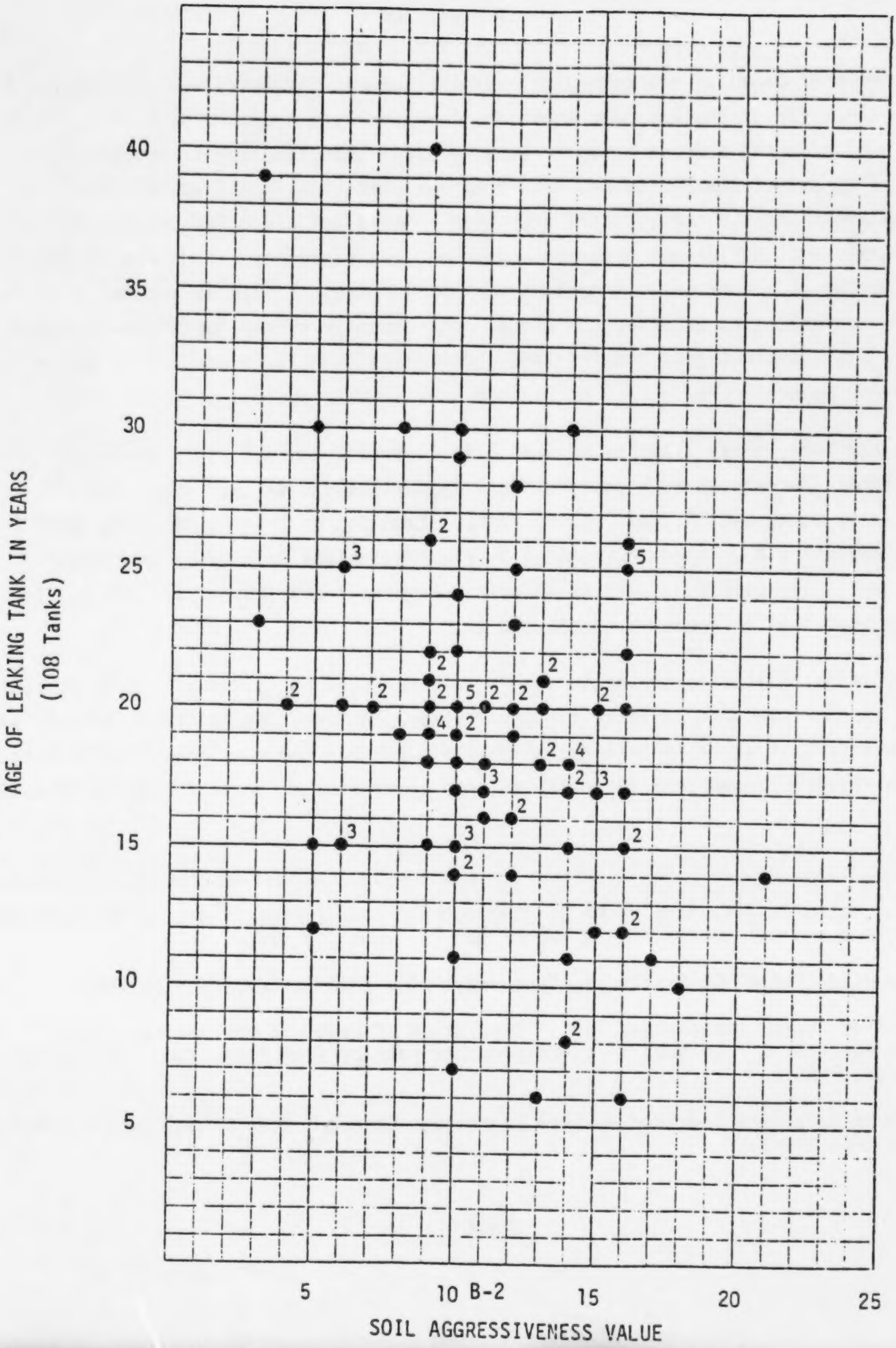

FIGURE 2

TASK FORCE NON-LEAKING TANK CHART

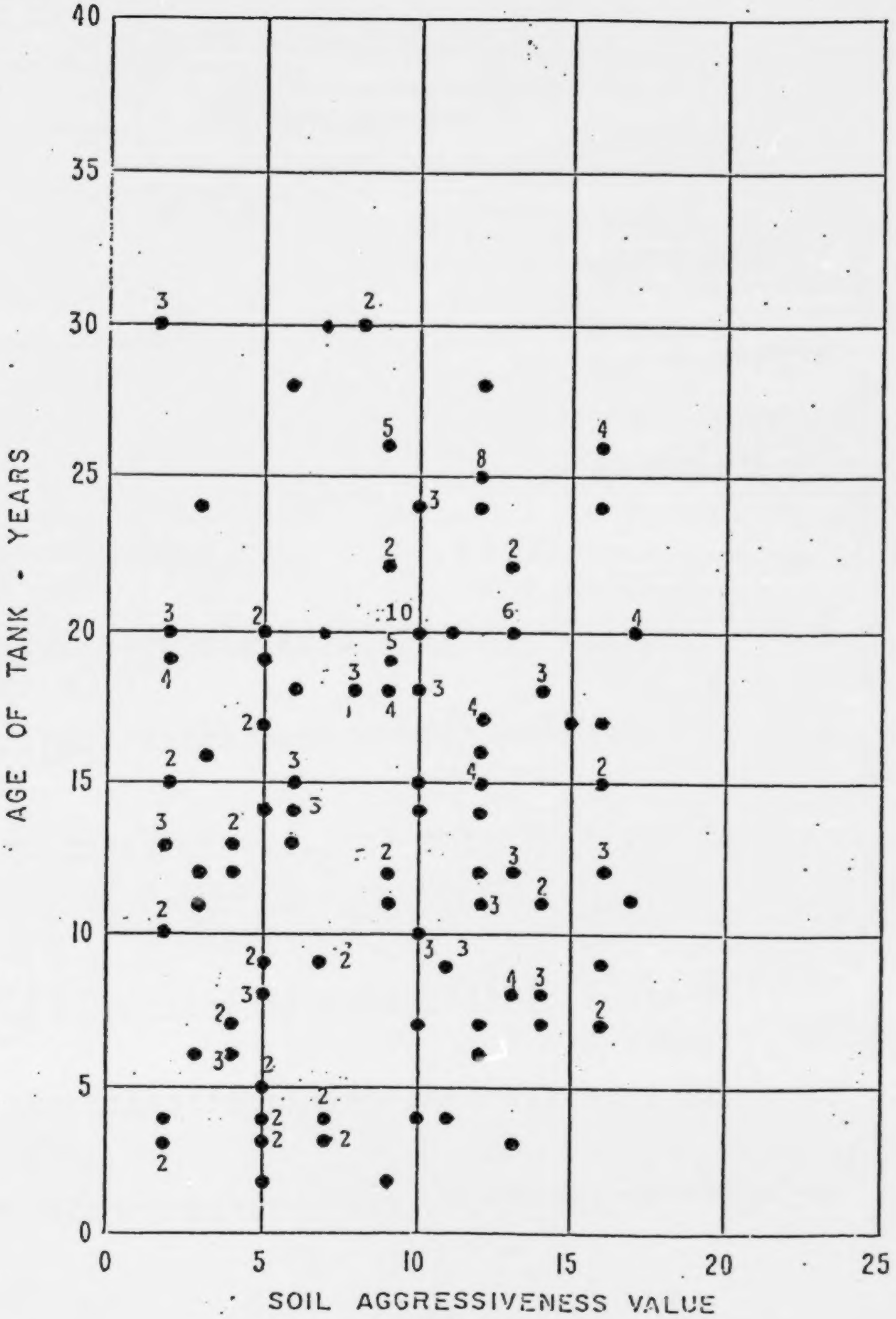

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TABLE 1

Soil Aggressiveness Values (SAV) and ages for leaking tanks.

Leaking tanks			Leaking tanks			Leaking tanks		
SAV	Age	Age*SAV	SAV	Age	Age*SAV	SAV	Age	Age*SAV
5	12	60	9	21	189	10	30	300
3	23	69	10	19	190	16	20	320
10	7	70	10	19	190	12	28	336
5	15	75	16	12	192	16	22	352
13	6	78	16	12	192	9	40	360
4	20	80	12	16	192	16	25	400
4	20	80	12	16	192	16	25	400
6	15	90	11	18	198	16	25	400
6	15	90	9	22	198	16	25	400
6	15	90	10	20	200	16	25	400
16	6	96	10	20	200	16	26	416
10	11	110	10	20	200	14	30	420
14	8	112	10	20	200			
14	8	112	10	20	200			
3	39	117	14	15	210			
6	20	120	11	20	220			
9	15	135	11	20	220			
10	14	140	10	22	220			
10	14	140	12	19	228			
7	20	140	13	18	234			
7	20	140	13	18	234			
10	15	150	9	26	234			
10	15	150	9	26	234			
10	15	150	14	17	238			
6	25	150	14	17	238			
6	25	150	16	15	240			
6	25	150	16	15	240			
5	30	150	12	20	240			
8	19	152	12	20	240			
14	11	154	10	24	240			
9	18	162	8	30	240			
12	14	168	14	18	252			
10	17	170	14	18	252			
9	19	171	14	18	252			
9	19	171	14	18	252			
9	19	171	15	17	255			
9	19	171	15	17	255			
11	16	176	15	17	255			
18	10	180	13	20	260			
15	12	180	16	17	272			
10	18	180	13	21	273			
9	20	180	13	21	273			
9	20	180	12	23	276			
17	11	187	10	29	290			
11	17	187	21	14	294			
11	17	187	15	20	300			
11	17	187	15	20	300			
9	21	189	12	25	300			

TABLE 1

Soil Aggressiveness Values (SAV) and ages for leaking tanks.

	Leaking tanks	
SAV	Age	Age*SAV
5	12	60
3	23	69
10	7	70
5	15	75
13	6	78
4	20	80
4	20	80
6	15	90
6	15	90
6	15	90
16	6	96
10	11	110
14	8	112
14	8	112
3	39	117
6	20	120
9	15	135
10	14	140
10	14	140
7	20	140
7	20	140
10	15	150
10	15	150
10	15	150
6	25	150
6	25	150
6	25	150
5	30	150
8	19	152
14	11	154
9	18	162
12	14	168
10	17	170
9	19	171
9	19	171
9	19	171
9	19	171
11	16	176
18	10	180
15	12	180
10	18	180
9	20	180
9	20	180
17	11	187
11	17	187
11	17	187
11	17	187
9	21	189

	Leaking tanks	
SAV	Age	Age*SAV
9	21	189
10	19	190
10	19	190
16	12	192
16	12	192
12	16	192
12	16	192
11	18	198
9	22	198
10	20	200
10	20	200
10	20	200
10	20	200
10	20	200
14	15	210
11	20	220
11	20	220
10	22	220
12	19	228
13	18	234
13	18	234
9	26	234
9	26	234
14	17	238
14	17	238
16	15	240
16	15	240
12	20	240
12	20	240
10	24	240
8	30	240
14	18	252
14	18	252
14	18	252
14	18	252
15	17	255
15	17	255
15	17	255
13	20	260
16	17	272
13	21	273
13	21	273
12	23	276
10	29	290
21	14	294
15	20	300
15	20	300
12	25	300

	Leaking tanks	
SAV	Age	Age*SAV
10	30	300
16	20	320
12	28	336
16	22	352
9	40	360
16	25	400
16	25	400
16	25	400
16	25	400
16	25	400
16	26	416
14	30	420

TABLE 2

Soil Aggressiveness Values (SAV) and ages for non-leaking tanks.

Non-leakers			Non-leakers			Non-leakers			Non-leakers		
SAV	Age	SAV*Age	SAV	Age	SAV*Age	SAV	Age	SAV*Age	SAV	Age	SAV*Age
2	3	6	4	13	52	16	9	144	12	17	204
2	3	6	2	30	60	12	12	144	12	17	204
2	4	8	2	30	60	8	18	144	7	30	210
5	2	10	2	30	60	8	18	144	11	20	220
5	3	15	7	9	63	8	18	144	9	26	234
5	3	15	7	9	63	10	15	150	9	26	234
9	2	18	10	7	70	14	11	154	9	26	234
3	6	18	5	14	70	14	11	154	9	26	234
5	4	20	12	6	72	13	12	156	9	26	234
5	4	20	3	24	72	13	12	156	16	15	240
2	10	20	6	13	78	13	12	156	16	15	240
2	10	20	12	7	84	9	18	162	10	24	240
7	3	21	6	14	84	9	18	162	10	24	240
7	3	21	6	14	84	9	18	162	10	24	240
4	6	24	6	14	84	9	18	162	8	30	240
4	6	24	5	17	85	12	14	168	8	30	240
4	6	24	5	17	85	6	28	168	14	18	252
5	5	25	6	15	90	9	19	171	14	18	252
5	5	25	6	15	90	9	19	171	14	18	252
2	13	26	6	15	90	9	19	171	15	17	255
2	13	26	5	19	95	9	19	171	13	20	260
2	13	26	14	7	98	9	19	171	13	20	260
7	4	28	11	9	99	12	15	180	13	20	260
7	4	28	11	9	99	12	15	180	13	20	260
4	7	28	11	9	99	12	15	180	13	20	260
4	7	28	9	11	99	12	15	180	13	20	260
2	15	30	10	10	100	10	18	180	16	17	272
2	15	30	10	10	100	10	18	180	13	22	286
3	11	33	10	10	100	10	18	180	13	22	286
3	12	36	5	20	100	17	11	187	12	24	288
2	19	38	5	20	100	16	12	192	12	25	300
2	19	38	13	8	104	16	12	192	12	25	300
2	19	38	13	8	104	16	12	192	12	25	300
2	19	38	13	8	104	12	16	192	12	25	300
13	3	39	13	8	104	9	22	198	12	25	300
10	4	40	9	12	108	9	22	198	12	25	300
5	8	40	9	12	108	10	20	200	12	25	300
5	8	40	6	18	108	10	20	200	12	25	300
5	8	40	16	7	112	10	20	200	12	28	336
2	20	40	16	7	112	10	20	200	17	20	340
2	20	40	14	8	112	10	20	200	17	20	340
2	20	40	14	8	112	10	20	200	17	20	340
11	4	44	14	8	112	10	20	200	17	20	340
5	9	45	12	11	132	10	20	200	16	24	384
5	9	45	12	11	132	10	20	200	16	26	416
4	12	48	12	11	132	10	20	200	16	26	416
3	16	48	10	14	140	12	17	204	16	26	416
4	13	52	7	20	140	12	17	204	16	26	416

TABLE 3

Soil Aggressiveness Values (SAV) and ages for leaking tanks.

Leaking tanks

SAV	Age	Age*SAV
13	6	78
16	6	96
10	7	70
14	8	112
14	8	112
18	10	180
10	11	110
14	11	154
17	11	187
5	12	60
15	12	180
16	12	192
16	12	192
10	14	140
10	14	140
12	14	168
21	14	294
5	15	75
6	15	90
6	15	90
6	15	90
9	15	135
10	15	150
10	15	150
10	15	150
14	15	210
16	15	240
16	15	240
11	16	176
12	16	192
12	16	192
10	17	170
11	17	187
11	17	187
11	17	187
14	17	238
14	17	238
15	17	255
15	17	255
15	17	255
16	17	272
9	18	162
10	18	180
11	18	198
13	18	234
13	18	234
14	18	252
14	18	252
14	18	252
14	18	252
8	19	152
9	19	171
9	19	171
9	19	171
9	19	171
10	19	190
10	19	190
12	19	228
4	20	80
4	20	80
6	20	120
7	20	140
7	20	140
9	20	180
9	20	180
10	20	200
10	20	200
10	20	200
10	20	200
10	20	200
11	20	220
11	20	220
12	20	240
12	20	240
13	20	260
15	20	300
15	20	300
16	20	320
9	21	189
9	21	189
13	21	273
13	21	273
9	22	198
10	22	220
16	22	352
3	23	69
12	23	276
10	24	240
6	25	150
6	25	150
6	25	150
12	25	300
16	25	400
16	25	400
16	25	400
16	25	400
16	25	400
9	26	234
9	26	234
16	26	416
12	28	336
10	29	290
5	30	150
8	30	240
10	30	300
14	30	420
3	39	117
9	40	360

TABLE 3

Soil Aggressiveness Values (SAV) and ages for leaking tanks.

Leaking tanks			Leaking tanks			Leaking tanks		
SAV	Age	Age*SAV	SAV	Age	Age*SAV	SAV	Age	Age*SAV
13	6	78	14	18	252	16	25	400
16	6	96	14	18	252	9	26	234
10	7	70	8	19	152	9	26	234
14	8	112	9	19	171	16	26	416
14	8	112	9	19	171	12	28	336
18	10	180	9	19	171	10	29	290
10	11	110	9	19	171	5	30	150
14	11	154	10	19	190	8	30	240
17	11	187	10	19	190	10	30	300
5	12	60	12	19	228	14	30	420
15	12	180	4	20	80	3	39	117
16	12	192	4	20	80	9	40	360
16	12	192	6	20	120			
10	14	140	7	20	140			
10	14	140	7	20	140			
12	14	168	9	20	180			
21	14	294	9	20	180			
5	15	75	10	20	200			
6	15	90	10	20	200			
6	15	90	10	20	200			
6	15	90	10	20	200			
9	15	135	10	20	200			
10	15	150	11	20	220			
10	15	150	11	20	220			
10	15	150	12	20	240			
14	15	210	12	20	240			
16	15	240	13	20	260			
16	15	240	15	20	300			
11	16	176	15	20	300			
12	16	192	16	20	320			
12	16	192	9	21	189			
10	17	170	9	21	189			
11	17	187	13	21	273			
11	17	187	13	21	273			
11	17	187	9	22	198			
14	17	238	10	22	220			
14	17	238	16	22	352			
15	17	255	3	23	69			
15	17	255	12	23	276			
15	17	255	10	24	240			
16	17	272	6	25	150			
9	18	162	6	25	150			
10	18	180	6	25	150			
11	18	198	12	25	300			
13	18	234	16	25	400			
13	18	234	16	25	400			
14	18	252	16	25	400			
14	18	252	16	25	400			

TABLE 4

Soil Aggressiveness Values (SAV) and ages for non-leaking tanks.

SAV	Age	SAV*Age	SAV	Age	SAV*Age	SAV	Age	SAV*Age	SAV	Age	SAV*Age
5	2	10	2	10	20	3	16	48	10	20	200
9	2	18	2	10	20	12	16	192	10	20	200
2	3	6	10	10	100	5	17	85	11	20	220
2	3	6	10	10	100	5	17	85	13	20	260
5	3	15	10	10	100	12	17	204	13	20	260
5	3	15	3	11	33	12	17	204	13	20	260
7	3	21	9	11	99	12	17	204	13	20	260
7	3	21	12	11	132	12	17	204	13	20	260
13	3	39	12	11	132	15	17	255	13	20	260
2	4	8	12	11	132	16	17	272	17	20	340
5	4	20	14	11	154	6	18	108	17	20	340
5	4	20	14	11	154	8	18	144	17	20	340
7	4	28	17	11	187	8	18	144	17	20	340
7	4	28	3	12	36	8	18	144	9	22	198
10	4	40	4	12	48	9	18	162	9	22	198
11	4	44	9	12	108	9	18	162	13	22	286
5	5	25	9	12	108	9	18	162	13	22	286
5	5	25	12	12	144	9	18	162	3	24	72
3	6	18	13	12	156	10	18	180	10	24	240
4	6	24	13	12	156	10	18	180	10	24	240
4	6	24	13	12	156	10	18	180	10	24	240
4	6	24	16	12	192	14	18	252	12	24	288
12	6	72	16	12	192	14	18	252	16	24	384
4	7	28	16	12	192	14	18	252	12	25	300
4	7	28	2	13	26	2	19	38	12	25	300
10	7	70	2	13	26	2	19	38	12	25	300
12	7	84	2	13	26	2	19	38	12	25	300
14	7	98	4	13	52	2	19	38	12	25	300
16	7	112	4	13	52	5	19	95	12	25	300
16	7	112	6	13	78	9	19	171	12	25	300
5	8	40	5	14	70	9	19	171	12	25	300
5	8	40	6	14	84	9	19	171	9	26	234
5	8	40	6	14	84	9	19	171	9	26	234
13	8	104	6	14	84	9	19	171	9	26	234
13	8	104	10	14	140	2	20	40	9	26	234
13	8	104	12	14	168	2	20	40	9	26	234
13	8	104	2	15	30	2	20	40	16	26	416
14	8	112	2	15	30	5	20	100	16	26	416
14	8	112	6	15	90	5	20	100	16	26	416
14	8	112	6	15	90	7	20	140	16	26	416
5	9	45	6	15	90	10	20	200	6	28	168
5	9	45	10	15	150	10	20	200	12	28	336
7	9	63	12	15	180	10	20	200	2	30	60
7	9	63	12	15	180	10	20	200	2	30	60
11	9	99	12	15	180	10	20	200	2	30	60
11	9	99	12	15	180	10	20	200	7	30	210
11	9	99	16	15	240	10	20	200	8	30	240
16	9	144	16	15	240	10	20	200	8	30	240

TABLE 4

Soil Aggressiveness Values (SAV) and ages for non-leaking tanks.

SAV	Age	SAV*Age	SAV	Age	SAV*Age	SAV	Age	SAV*Age	SAV	Age	SAV*Age
5	2	10	2	10	20	3	16	48	10	20	200
9	2	18	2	10	20	12	16	192	10	20	200
2	3	6	10	10	100	5	17	85	11	20	220
2	3	6	10	10	100	5	17	85	13	20	260
5	3	15	10	10	100	12	17	204	13	20	260
5	3	15	3	11	33	12	17	204	13	20	260
7	3	21	9	11	99	12	17	204	13	20	260
7	3	21	12	11	132	12	17	204	13	20	260
13	3	39	12	11	132	15	17	255	13	20	260
2	4	8	12	11	132	16	17	272	17	20	340
5	4	20	14	11	154	6	18	108	17	20	340
5	4	20	14	11	154	8	18	144	17	20	340
7	4	28	17	11	187	8	18	144	17	20	340
7	4	28	3	12	36	8	18	144	9	22	198
10	4	40	4	12	48	9	18	162	9	22	198
11	4	44	9	12	108	9	18	162	13	22	286
5	5	25	9	12	108	9	18	162	13	22	286
5	5	25	12	12	144	9	18	162	3	24	72
3	6	18	13	12	156	10	18	180	10	24	240
4	6	24	13	12	156	10	18	180	10	24	240
4	6	24	13	12	156	10	18	180	10	24	240
4	6	24	16	12	192	14	18	252	12	24	288
12	6	72	16	12	192	14	18	252	16	24	384
4	7	28	16	12	192	14	18	252	12	25	300
4	7	28	2	13	26	2	19	38	12	25	300
10	7	70	2	13	26	2	19	38	12	25	300
12	7	84	2	13	26	2	19	38	12	25	300
14	7	98	4	13	52	2	19	38	12	25	300
16	7	112	4	13	52	5	19	95	12	25	300
16	7	112	6	13	78	9	19	171	12	25	300
5	8	40	5	14	70	9	19	171	12	25	300
5	8	40	6	14	84	9	19	171	9	26	234
5	8	40	6	14	84	9	19	171	9	26	234
13	8	104	6	14	84	9	19	171	9	26	234
13	8	104	10	14	140	2	20	40	9	26	234
13	8	104	12	14	168	2	20	40	9	26	234
13	8	104	2	15	30	2	20	40	16	26	416
14	8	112	2	15	30	5	20	100	16	26	416
14	8	112	6	15	90	5	20	100	16	26	416
14	8	112	6	15	90	7	20	140	16	26	416
5	9	45	6	15	90	10	20	200	6	28	168
5	9	45	10	15	150	10	20	200	12	28	336
7	9	63	12	15	180	10	20	200	2	30	60
7	9	63	12	15	180	10	20	200	2	30	60
11	9	99	12	15	180	10	20	200	2	30	60
11	9	99	12	15	180	10	20	200	7	30	210
11	9	99	16	15	240	10	20	200	8	30	240
16	9	144	16	15	240	10	20	200	8	30	240

FIGURE 3: COMPUTATION OF SAV

I BASIC CHARACTERISTICS		POINTS
o Soil Resistivity	<300	12
	300 - 1,000	10
	1,000 - 2,000	8
	2,000 - 5,000	6
	5,000 - 10,000	3
	10,000 - 25,000	1
	>25,000	0
o Soil pH	<3	8
	3 - 5	6
	5 - 6.5	4
	6.5 - 7.5	2
	7.5 - 9	1
	>9	0
o Soil Moisture	Saturated	3
	Damp	2
	Dry	0
II DIFFERENTIAL CHARACTERISTICS		
o Resistivity (ratio of extremes)	>1:10	3
	>1: 5	2
	>1: 3	1
	<1: 3	0
Soil pH (Difference in pH Value)	3	2
	1.5 - 3	1
	0 - 1.5	0
III SULFIDES		
	Positive	4
	Negative	0

corrosivities; that is, a soil with an SAV of 2x is expected to be (on average) twice as corrosive as a soil with an SAV of x.

On first consideration, the Canadian data reveals one important fact: there is a lot of scatter. But it is also clear that non-leaking tanks are clustered somehwat closer to the lower left-hand corner of the diagram than are leaking tanks. Thus, age, SAV, or the combination of the two does appear to have some predictive effect on the probability of leakage.

This tentative conclusion can be verified by simple statistical analyses. Using chi-squared techniques, age, SAV and SAV x age can be tested for statistically significant effects on the probability of leakage. In addition, SAV can be tested to determine if it has any effect independent from the effect of age. The following section will describe each of these analyses.

STATISTICAL TESTS

1. SAV x Age

PACE asserts that the product of SAV and tank age is an appropriate predictor for tank leakage. This assertion makes intuitive sense, for it would appear to allow for the continuing effects of various types of soils. It is also born out by the data, as is indicated by the following contingency table:

TABLE 5

SAV x Age	Number of Leaking Tanks	Number of Non-Leaking Tanks	
0 - 49	0 / 16.92	47 / 30.08	47
50 - 99	11 / 13.68	27 / 24.32	38
100 - 149	10 / 13.32	27 / 23.68	37
150 - 199	36 / 24.12	31 / 42.88	67
200 - 249	22 / 18.00	28 / 32.00	50
250 - 299	14 / 10.08	14 / 17.92	28
300 - 399	8 / 7.92	14 / 14.08	22
≥ 400	7 / 3.96	4 / 7.04	11
	108	192	300

Each cell of this table contains two numbers. The first represents the observed observed number of tanks in each category; these numbers were obtained from Tables 1 and 2. The second number in each cell represents the expected number of tanks falling into that category if SAV x Age had no effect on the probability of leakage. These numbers are computed by multiplying the row total by the column total and dividing by the grand total (300).

One of the assumptions underlying the chi-squared test is that the sampled size is large enough to allow a large-sample approximation. Often, this assumption is expressed as a requirement that there be at least 5 observations in each cell, but more rigorously, the assumption may be stated as a requirement that the expected values be greater than 5 in at least 80% of the sample cells.[5] This assumption is clearly met.

The test statistic (T) is simply the summation of $(x_{ij} - E_{ij})^2/E_i$, over all cells, where x_{ij} is the number of observations in cell_{ij} and E_{ij} is the corresponding expected number of observations. For Table 3, T = 45.11, with $(r-1) \cdot (c-1) = 7$ degrees of freedom (r and c are the numbers of rows and columns, respectively). This is highly significant, indicating that there is far less than a .1% chance that the difference between the SAV x Age distributions of leaking and non-leaking tanks is random. SAV x Age is therefore a statistically significant factor in the differentiation of leaking and non-leaking tanks. In particular, it appears from Table 5 that SAV x Age has a trichotomous effect. For very low values of SAV x Age, there were no observed leaking tanks (the raw data indicates that for all leaking tanks SAV x Age > 59). For intermediate values (50 < SAV x Age < 150), approximately 28% were leaking, and for high values (SAV x Age > 149), approximately 49% were leaking.

2. Tank Age

The conventional wisdom is that age is a very poor predictor of tank leakage. This, however, is an overstatement, as is evident from the following contingency table:

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[5] W. J. Conover, Practical Nonparametric Statistics (John Wiley & Sons: New York), 1971, p. 152.

TABLE 6

Tank Age (yrs)	Number of Leaking Tanks	Number of Non-Leaking Tanks	
0 - 4	0 / 5.76	16 / 10.24	16
5 - 9	5 / 13.32	32 / 23.68	37
10 - 14	12 / 17.28	36 / 30.72	48
15 - 19	41 / 31.32	46 / 55.68	87
20 - 24	30 / 24.12	37 / 42.88	67
25 - 29	14 / 11.88	19 / 21.12	33
> 29	6 / 4.32	6 / 7.68	12
	108	192	300

For this table, T = 28.17, with 6 degrees of freedom. This is significant at something in excess of the 99.9% level. Age therefore is a statistically significant determinant of the probability of leakage. It is clear from Table 1 that while some tanks are leaking at ages 5 to 14, they represent a fairly small fraction (17%) of the entire sample. After age 15, however, the percentage of leakers increases to 46%.

Another interesting observation also emerges from Table 6: if a new contingency table is constructed only for tanks of age 15 or higher, there is no statistically significant effect of age upon the probability of leakage:

TABLE 7

Tank Age	Number of Leaking Tanks	Number of Non-Leaking Tanks	
15 - 19	41 / 39.78	46 / 47.22	87
20 - 24	30 / 30.68	37 / 36.36	67
25 - 29	14 / 15.09	19 / 17.91	33
> 29	6 / 5.49	6 / 6.51	12
	91	108	199

For this table, T = .33, with 3 degrees of freedom. This is not significant, even at the 75% level. Thus, age seems to have an effect only for tanks younger than 15 years; above that age, the probability of leakage is apparently constant.

3. SAV

A contingency table can also be set up to test the effect of SAV upon the probability of leakage:

TABLE 8

SAV	Number of Leaking Tanks	Number of Non-Leaking Tanks	
0 - 4	4 / 13.32	33 / 23.68	37
5 - 9	28 / 31.68	60 / 56.32	88
10 - 14	53 / 47.52	79 / 84.48	132
> 14	23 / 15.48	20 / 27.52	43
	108	192	300

For this table, T = 17.55 with 3 degrees of freedom. This is significant at the 99.9% level.

4. Interaction of SAV and Age

Unfortunately, Age and SAV are not independent variables, as is shown by Table 9:

TABLE 9

	Soil Aggressiveness Value			
Age of Tank	Low (0-6)	Medium (7-12)	High (>12)	
0 - 14 years	37 / 24.91	32 / 47.47	32 / 28.62	101
15 - 20 years	26 / 33.05	72 / 62.98	36 / 37.97	134
> 20 years	11 / 16.03	37 / 30.55	17 / 18.42	65
	74	141	85	300

The T statistic for this table is 17.26 with 4 degrees of freedom. This indicates that there is less than a .5% chance that SAV and Age are uncorrelated. An examination of Table 9 shows that the strongest correlation appears to occur for low and medium SAV's. High-SAV tanks are fairly randomly distributed across all three age groups.

This correlation would be easy to explain if older tanks were more likely common to be found in low-SAV soils; in that case, the relationship between Age and SAV would simply be due to a survival factor (a disproportionate number of older tanks in aggressive soils would already have been replaced long before the survey was taken). Such, however, is not the case. Instead, younger tanks are more likely to be found in low-SAV soils. This cannot be a survival effect. Instead, it probably represents a shift in installation practices in favor of the less corrosive soils.

The correlation between tank age and SAV makes it difficult to determine which is the dominant variable. It is possible, for example, that the observed effects of SAV and SAV x Age are actually the effects of Age, transmitted through the linkages among these variables.

This hypothesis can be tested by constructing contingency tables examining the effects of SAV upon tank leakage for each of the tank age-groups. This will reveal whether SAV has any effect independent from Age.

TABLE 10

Young Tanks
(T = 12.34, 99.5% significance)

	Number of Leaking Tanks	Number of Non-Leaking Tanks	
Low SAV	1 / 6.23	36 / 30.77	37
Medium SAV	5 / 5.39	27 / 26.61	32
High SAV	11 / 5.39	21 / 26.61	32
	17	84	101

Medium-age Tanks
(T = 4.67, 90% significance)

	Number of Leaking Tanks	Number of Non-Leaking Tanks	
Low SAV	7 / 11.84	19 / 14.16	26
Medium SAV	35 / 32.78	37 / 39.22	72
High SAV	19 / 16.39	17 / 19.61	36
	61	73	134

Old Tanks
(T = 2.44, insignificant)

	Number of Leaking Tanks	Number of Non-Leaking Tanks	
Low SAV	6 / 5.08	5 / 5.92	11
Medium SAV	14 / 17.08	23 / 19.92	37
High SAV	10 / 7.85	7 / 9.15	17
	30	35	65

These tables indicate that SAV and Age have some independent effect, but only for the younger tanks. Combining the results of Tables 10 and 7, it appears that neither Age nor SAV have much effect for tanks older than 20 years.

DATA ANALYSIS

Proving that there are statistically significant linkages between leakage rates and SAV, Age, and SAV x Age does not conclude the analysis, however, for it is also necessary to determine the correct interpretation of these linkages. The ultimate goal of such an interpretation is to deduce a cumulative probability distribution for tank failure over a range of SAV x Age categories. Unfortunately, this is not a straightforward task.

One approach to this problem is to assume that the data actually represent the desired cumulative distributions. This assumption would be correct if leaking tanks were never repaired or replaced, for in that case, the number of leaking tanks in any SAV x Age bracket would include both new and pre-existing leaks. Under this simple assumption, the Canadian data yields the following distribution (obtained from the numbers in Table 5):

TABLE 11

SAV x Age	Cumulative Leak Probability (%)
0-49	0
50-99	28.9
100-149	27.0
150-199	53.7
200-249	44.0
250-299	50.0
300-399	36.4
≥ 400	63.6

Since a cumulative probability distribution is by definition non-decreasing, the fluctuation in 300-399 category must be assumed to be anomolous. It can be reduced by combining the two highest brackets:

TABLE 12

SAV x Age	Cumulative Leak Probability %
0-49	0
50-99	28.9
100-149	27.0
150-199	53.7
200-249	44.0
250-299	50.0
≥ 300	45.0

This distribution reveals that tank failure occurs in two spurts: one at SAV x Age between 50 and 99, and the other at SAV x Age between 150 and 199. Other fluctuations in failure rates are statistically insignificant, as can be verified by constructing the appropriate contingency tables.

This distribution has the advantage that it conforms to the expected sigmoidal pattern, with most of the failures occurring during the middle brackets and with some tanks which are effectively immortal even in highly aggressive soils, but the numbers in Table 12 do not seem appropriate. Leakage should not occur at such tightly defined intervals; i.e. there are too few leakers in the 100-149 category. Even more importantly, there are too many immortals. It is very unlikely that half of the tanks would still survive after 40 years in a soil of SAV = 10 (or 20 years with SAV = 20). Yet that is what this distribution seems to indicate.

The problem with the distribution in Table 12 is simple: some leaking tanks will have been replaced relatively soon after they began to leak. Thus, in the upper brackets the survey self-selects for non-leaking tanks (since they are more likely to still be in use), and the cumulative percentages are too low.

One way to cure this problem would be to convert the survey data into a cumulative distribution by computing the number of missing tanks. This could be done by determining the relative numbers of tanks buried in each year and assigning these to SAV brackets according to the distributions in Table 10.[6] To the extent that Table 11 underrepresents certain SAV x Age groups, it can then be assumed that the missing tanks are those which have previously leaked, and the cumulative probabilities can be adjusted accordingly. In order to normalize these calculations, it must be assumed that one SAV x Age-bracket is fully represented. Presumably, this would be bracket 0-49.

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[6] This apportionment assumes that the missing tanks in each age group followed the

Unfortunately, this analysis is fraught with difficulties. Not only are the calculations complex (and somewhat recursive), but the necessary tank burial data is not available. Instead, the best alternative are three data sources on service station construction, and even these are difficult to obtain for Canada (U.S. data are presented in Table 13). Furthermore, once the data are assembled, it appears that the Canadian survey underrepresents younger tanks. This indicates either serious problems in the application of U.S. service station data to Canadian tank burials, or it indicates that the Canadian survey was not random, but instead favored older tanks. In either event, tank attrition cannot be computed, and another approach must be used to obtain a more reasonable cumulative distribution.

A simpler approach to the problem of self-selection of older non-leaking tanks may be found by varying the assumptions underlying Table 12. Instead of assuming that leaks are never detected before the survey, it can be assumed instead that all leaks are detected and the tanks replaced before enough time has passed for the tank to move into the next SAV x Age category. This assumption requires the detection period to be inversely proportional to SAV, but that requirement would be sensible if monitoring is better for tanks known to be in more aggressive soils.

Under this assumption, the failure rates in Table 12 become elements of a probability density function and the corresponding cumulative distribution may be calculated.

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same SAV distributions as their surviving kin. Such an assumption is probably not accurate, but it is better than nothing.

TABLE 13[1]

Date	Number of Service Stations[2]	Change in Number of Service Stations	API Reports[3] of New Service Stations	API Deactivations[3]	Building[4] Permits	Ratio of Rehabilitations to new Constructions[5]	Number of Rehabilitations[6]
1948	179,647	350					
1949	-	350					
1950	180,347	350					
1951	180,697	350					
1952	181,040	343					
1953	181,390	350					
1954	181,747*	357			9,021	24.30	8664
1955	188,100	6353			9,826	0.55	3473
1956	194,600	6500			10,615	0.63	4115
1957	200,100	5500			5,391	0.00	(109)
1958	206,755	6655			7,801	0.17	1146
1959	207,800	1045			8,050	6.70	7005
1960	208,800	1000					
1961	209,700	900					
1962	210,600	900					
1963	211,473*	873			6,080	5.96	5207
1964	212,600	1127			6,150	4.46	5023
1965	213,550	950			6,500	5.84	5550
1966	214,500	950			6,275	5.60	5325
1967	216,059*	1559			6,606	3.24	5047
1968	219,100	3041	3740	4554	6000-7000	1.14	3500
1969	222,200	3100			6,200	1.00	3100
1970	222,000	(200)	2508	3586			
1971	220,000	(2000)	2068	3630			
1972	226,459*	6459	1689	3498			

TABLE 13 (Continued)

Date	Number of Service Stations	Change in Number of Service Stations	API Reports of New Service Stations	API Deactivations	Building Permits	Ratio of Rehabilitations to new Constructions	Number of Rehabilitations
1973	215,880	(579)	1172	9342			
1974	196,130	(19,750)	206	6041		9.0	1854
1975	189,480	(6,650)	206	4127		3.8	783
1976	186,340	(3,140)	319	5676		3.03	967
1977	176,400*	(9,940)	284	5683		6.16	1749
1978	172,300	(4,100)	353	5138			
1979	164,790	(7,510)	286	3724		8.34	2385
1980	158,540	(6,250)	169	3380		9.68	1636
1981	151,250	(7,290)	297	4273			
1982	147,000	(4,250)					

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[1] Source: National Petroleum News, annual Fact Book of petroleum statistics.

[2] Obtained by National Petroleum News (NPN) from U.S. government data and NPN estimates. Numbers marked by a star (*) are census totals.

[3] Obtained by NPN from American Petroleum Institute totals for a somewhat varying number of responding companies.

[4] Obtained by NPN from the Department of Labor, Bureau of Labor Statistics.

[5] From 1974 through 1980, these are obtained by NPN from an API survey. For 1954 through 1969, these numbers are obtained from columns 3 and 8.

[6] For 1954 through 1969, these numbers are the difference between the number of building permits issued and the change in the total number of service stations. For 1974 through 1980, these numbers are obtained from columns 4 and 7.

TABLE 14

SAV x Age	Probability of New Failure (%)	Cumulative Failure Probability (%)
0-49	0	0
50-99	28.9	28.9
100-149	27.0	46.7
150-199	53.7	75.3
200-249	44.0	86.2
250-299	50.0	93.1
300-399>	36.4	95.6
≥ 400	63.6	98.4

Unfortunately, these cumulative probabilities seem to be too high. Anecdotal data would seem to indicate that a larger percentage of tanks have extremely long lifetimes, even in very aggressive soils. Furthermore, it is likely that some leaks remain undetected over very long periods of time. For both of these reasons, the calculated failure rates are probably too high, though they probably can safely be used as upper bounds on the actual probabilities.[7]

A third assumption may be used in an effort to split the difference between the two polar cases discussed above: it may be assumed that 50% of the leaks detected in each bracket are new, while the remaining leaks are ones that have been continuing since a previous bracket. Under this assumption, the first two brackets are unaltered,[8] but for the other brackets, the previously leaking tanks must be removed from both the leaking tank category and the bracket totals. With these modifications, the data becomes:

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[7] There is another, more theoretical problem with Table 14: the cumulative probability distribution is highly dependent on the width of the SAV x Age brackets used in its computation. Decreasing their width increases the number of categories (without significantly changing the second column of the table), thereby causing the cumulative probability to converge upon 1.0 at a considerably more rapid rate. Broadening the categories has the reverse effect.

In non-mathematical terms, this problem is related to the detection-period problem discussed earlier. If leaks are detected rapidly, then the data indicates a high rate of new leak formation. If leaks are detected slowly, then the cumulative probability approaches the no-detection assumption depicted in Table 11. Since these problems relate to the proper interpretation of real-world data, they are not the same as the scenarios ultimately to be studied in the computer model. Instead, the goal is to determine just how conservative the Canadian oil companies' detection/repair policies actually were prior to 1977. The use of 50-point brackets seem to be a reasonable assumption for the technology then in use.

[8] The first bracket is unaltered because there are no leaks. The second bracket

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is unaltered because to alter it would be contrary to the observation that there are no failures in the first bracket.

TABLE 15

SAV x Age	Number of Leaking Tanks	Number of Previously Non-Leaking Tanks	Percent of New Leaks	Cumulative Leak Probability (%)
0-49	0	47	0	0
50-99	11	38	28.9	28.9
100-149	5	32	15.6	40.0
150-199	18	49	36.7	62.0
200-249	11	39	28.2	72.7
250-299	7	21	33.3	81.8
300-399	4	18	22.2	86.0
≥ 400	3.5	7.5	50.0	93.0

These cumulative probabilities from these three assumptions can be combined in a single table:

TABLE 16

SAV x Age	Lower Bound (Assumption 1)	Upper Bound (Assumption 2)	Assumption 3	Average of Assumption 1-3
0-49	0	0	0	0
50-99	28.9	28.9	28.9	28.9
100-149	27.0	46.7	40.0	37.9
150-199	53.7	75.3	62.0	63.7
200-249	44.0	86.2	72.7	67.6
250-299	50.0	93.1	81.8	75.0
300-399	45.0	95.6	86.0	75.5
≥ 400	45.0	98.4	93.0	78.8

The last column is the one which will be used in the Monte Carlo model, though it is subject to revisions as better data become available.

CAVEATS

The cumulative probability distribution presented in Table 16 must be used with caution, for unfortunately, the Canadian data set does not represent a random survey of existing tanks. Instead, the data were collected in 3 ways:[9]

- Over a 6-month period in 1977, all PACE member companies were requested to report leak incidents. Soil samples were taken at the leaking tanks' sites.
- During this same time period, PACE member companies were requested to report tank decommissionings. Decommissioned tanks were then tested for leaks, and soil samples were taken.
- Other tanks on the same site as a leaking or decommissioned tank were also tested.

Thus, the survey is biased both toward leaking tanks and toward older tanks. (The latter bias occurs because older tanks are more likely to be decommissioned). The age bias is relatively unimportant. The bias toward leaking tanks, however, means that the resulting data present a worst-case portrait of the existing tank situation. This bias may not be overly severe, however, for the fact that only 36% of the sample tanks were leaking indicates that the other two sampling methods may have predominated. Furthermore, this bias may be offset by the fact that the second and third sampling techniques tend to self-select for non-leaking tanks. Nevertheless, an unknown net bias probably results, and the data must be viewed as only an approximation of the results of a truly random survey.

AN ALTERNATIVE APPROACH

Instead of complex calculations based on Age x SAV, it may be more appropriate, given the data biases discussed above, to attempt a simpler model. With this in mind, the data can be grouped into high, middle, and low SAV soils, and failure rate versus age may be calculated for each soil group. The results are presented in Table 17.

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[9] PACE, "Underground Tank Systems," supra n. 1, p. 48, and personal communication with J.R. Clendening, Esso Petroleum. Canada, June 1985.

TABLE 17

	Low SAV (≤ 6)		Medium SAV (7-12)		High SAV (≥ 13)	
Tank Age	Leakers	Non Leakers	Leakers	Non Leakers	Leakers	Non Leake
0-4	0	8	0	7	0	1
5-9	0	13	1	8	4	11
10-14	1	15	4	12	7	9
15-19	4	14	22	25	15	7
20-24	4	6	19	18	7	13
≥ 25	5	4	8	17	7	4
	14	60	54	87	40	45

Table 17 may be interpreted under the same 3 assumptions that were used in Tables 11, 12, and 14-16. The resulting probability distributions are presented in Tables 18-20.

The same approach can also be used employing only two SAV categories. If soils are classified as benign when SAV is 9 or less and aggressive when SAV is 10 or greater, then the data can be summarized in Table 21.

Table 21 can be used to calculate cumulative probability distributions as in Tables 18-20. The results, using the same three assumptions, are presented in Tables 22-23.

The 2-part and 3-part SAV distinctions have certain similarities. In both cases, there are clear differences between soils of different aggressivities. These differences can most readily be appreciated by presenting the results in a single table, as is done in Table 24.

These distributions can be plotted graphically, as can the probability of tank failure versus SAV x Age (from Table 16). This is done in Figures 4-9. For interpretive purposes, these graphs have converted the cumulative distributions reported in the tables into the underlying probability densities. Thus, these histograms represent the probability that the tank failure will originate in each of the designated intervals.

These graphs indicate that SAV x Age is probably not the best measure of tank deterioration. The reason for this conclusion is the bimodal nature of the SAV x Age probability density. While such bimodality might possibly be an accurate reflection of the real world, it is more likely that the bimodal distribution results from improperly aggregating unlike distributions. This latter explanation appears particularly appropriate in the present situation. As Figures 4-6 indicate, the probability distributions are differently-shaped for low-SAV and high-SAV soils. Low-SAV soils produce a relatively steady failure rate for all years after year 9, while higher-SAV soils produce much higher failure rates in the lower years, but declining failure rates in later years.[10] Combining these

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[10] The reason for the low failure rates after year 19 is simply that by that year, a large fraction of high-SAV tanks have already failed.

TABLE 18. LOW SAV SOILS (SAV ≤ 6)

Cumulative Probability of Leakage (%)

Tank Age	Lower Bound (Detection within 5 years)	Upper Bound (No detection prior to survey)	Assumption 3[1] (75% of survey leaks are new)	Average
0-4	0	0	0	0
5-9	0	0	0	0
10-14	6.3	6.3	6.3	6.3
15-19	22.2	27.1	22.8	24.0
20-24	40.0	56.3	48.5	48.3
≥ 25	55.6	80.6	73.6	69.9

[1] Assumption 3 in this table has been adjusted from that used in Tables 15 and 16 in order to be consistent with the lower leak rates for low-SAV tanks.

TABLE 19. MEDIAN SAV SOILS (7-12)

Cumulative Probability of Leakage (%)

Tank Age	Lower Bound (Detection within 5 years)	Upper Bound (No detection prior to survey)	Assumption 3[1] (50% of survey leaks are new	Average
0-4	0	0	0	0
5-9	11.1	11.1	11.1	11.1
10-14	25.0	33.3	28.9[1]	29.1
15-19	46.8	64.5	50.6	54.0
20-24	51.4	82.8	67.7	67.3
≥ 25	32.0	88.3	73.8	-[2]

[1] This calculation uses a 75% rate of new leak development in order to be consistent with the lower-bound estimates in the previous column.

[2] No number is calculated for this range, for the anomalous decline in probability for the "lower bound" would produce an equally anomalous fluctuation in the average.

TABLE 20. HIGH SAV SOILS (SAV ≥ 13)

Cumulative Probability of Leakage (%)

Tank Age	Lower Bound (Detection within 5 years)	Upper Bound (No detection prior to survey	Assumption 3 (50% of survey leaks are new	Average
0-4	0	0	0	0
5-9	26.7	26.7	26.7	26.7
10-14	43.8	58.8	47.2	49.9
15-19	68.2	86.9	74.5	76.5
20-24	35.0	91.5	79.9	79.9[1]
≥ 25	63.6	96.9	89.3	83.3

[1] Obtained by interpolation between the values for ages 15-19 and ≥ 25. An average of Assumptions 1, 2, and 3 is dominated by the anomalous value for Assumption 1.

TABLE 21

	Benign Soils (SAV ≤ 9)		Aggressive Soils (SAV ≥ 10)	
Age	Number of Leaking Tanks	Number of Non-leaking Tanks	Number of Leaking Tanks	Number of Non-Leaking Tanks
0-4	0	13	0	3
5-9	0	15	5	17
10-14	1	18	11	18
15-19	11	26	30	20
20-24	11	9	19	28
≥ 25	9	12	11	13

TABLE 22. BENIGN SOILS (SAV ≤ 9)

Cumulative Probability of Leakage (%)

Tank Age	Lower Bound (Assuming no detection prior to survey	Upper Bound (Assuming all leaks detected and repaired within 5-year age bracket)	Assumption 3 (67% of observed leaks are new)	Average of Assumptions 1, 2, and 3
0-4	0	0	0	0
5-9	0	0	0	0
10-14	5.3	5.3	5.3	5.3
15-19	29.7	33.4	32.4[1]	31.8
20-24	55.0	70.0	62.8	62.6
≥ 25	42.9	82.9	75.2	67.0

[1] Calculated under the assumption that only one of the observed leakages was pre-existing, in order to be consistent with the preceding bracket's low-leak rate.

TABLE 23. AGGRESSIVE SOILS (SAV ≥ 10)

Cumulative Probability of Leakage (%)

Tank Age	Lower Bound (Assuming no detection prior to survey	Upper Bound (Assuming all leaks repaired within 5-year age bracket)	Assumption 3 (50% of observed leaks are new)	Average
0-4	0	0	0	0
5-9	22.7	22.7	22.7	22.7
10-14	37.9	52.0	48.1[1]	45.0
15-19	60.0	80.8	70.3	70.4
20-24	40.4	88.6	77.8	72.6[2]
≥ 25	45.8	93.8	84.4	74.7

[1] Calculated under the assumption that 80% of the observed leaks are new, in order to be consistent with the previous bracket's observed low leak rate.

[2] Calculated by interpolation between the preceding and following brackets, in order to prevent the decline in the value for assumption 1 from causing anomalous results.

TABLE 24.

Cumulative Probability of Leakage (%)

Tank Age[1]	Low SAV (0 to 6)	Medium SAV (7 to 12)	High SAV (≥ 13)	Benign Soil (0-9)	Aggressive Soil (≥ 10)
4	0	0	0	0	0
9	0	11.1	26.7	0	22.7
14	6.3	29.1	49.9	5.3	45.0
19	24.0	54.0	76.5	31.8	70.4
24	48.3	67.3	79.9	62.6	72.6
≥ 25	69.9	-	83.3	67.0	74.7

[1] Tank ages have been changed from age brackets to the age corresponding to the top of each bracket.

FIGURE 4
LOW SAV SOILS (0-6)

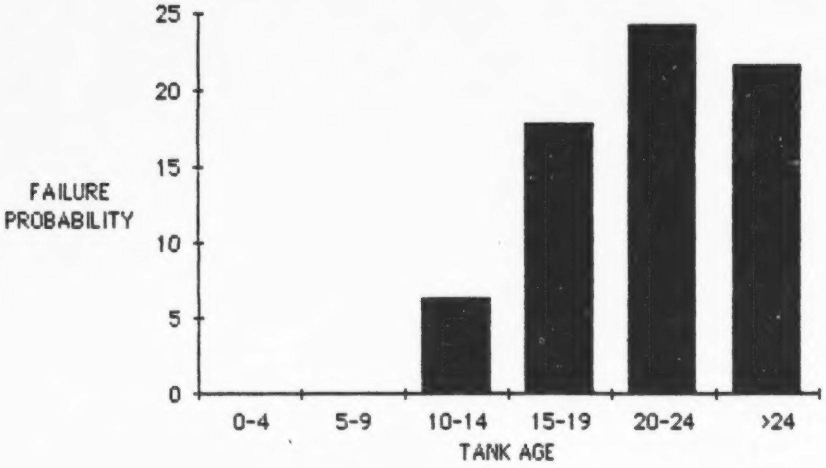


FIGURE 5

MEDIUM SAV SOILS (7-12)

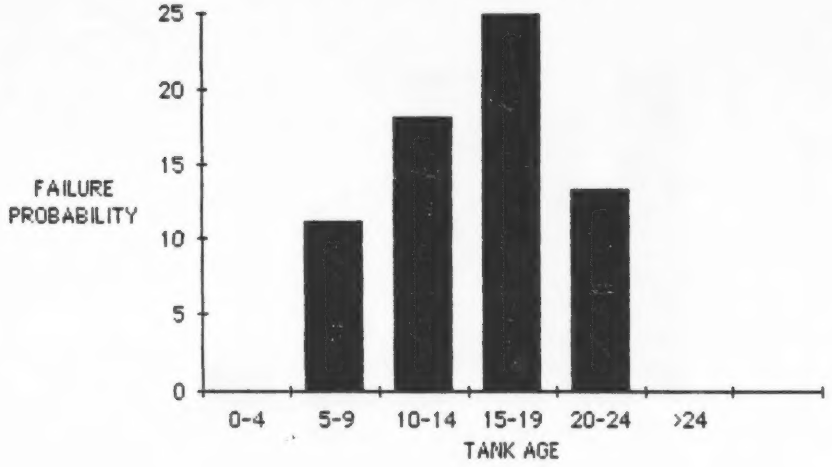


FIGURE 6
HIGH SAV SOILS (13-21)

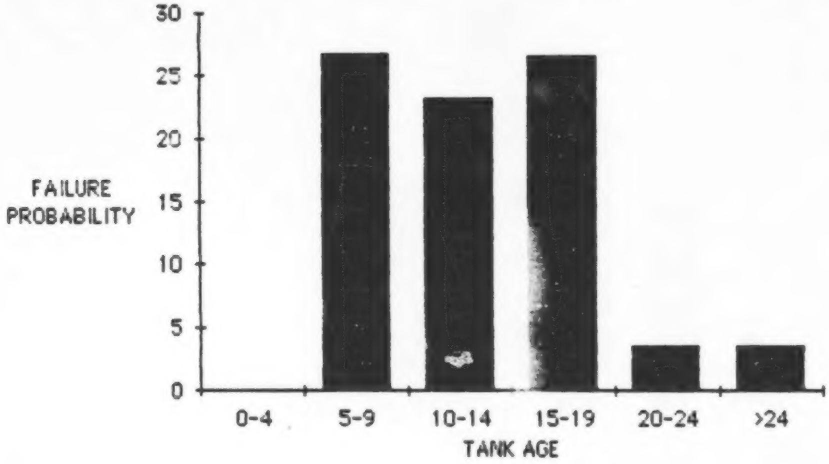


FIGURE 7
BENIGN SOILS (0-9)

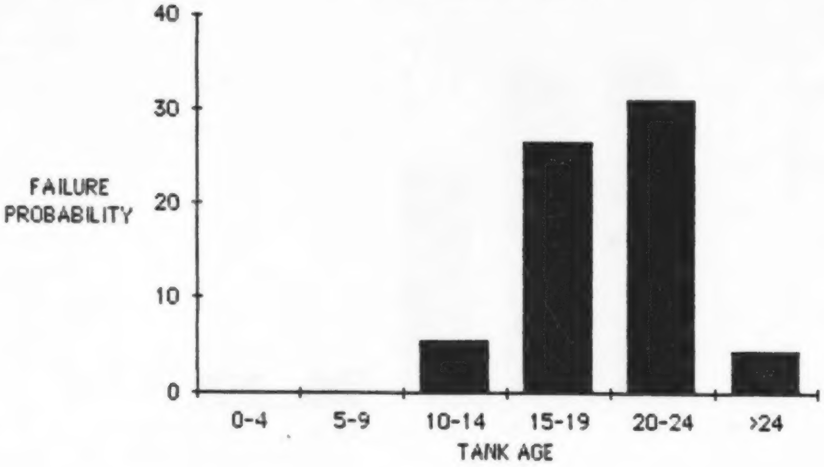


FIGURE 8

AGGRESSIVE SOILS (>10)

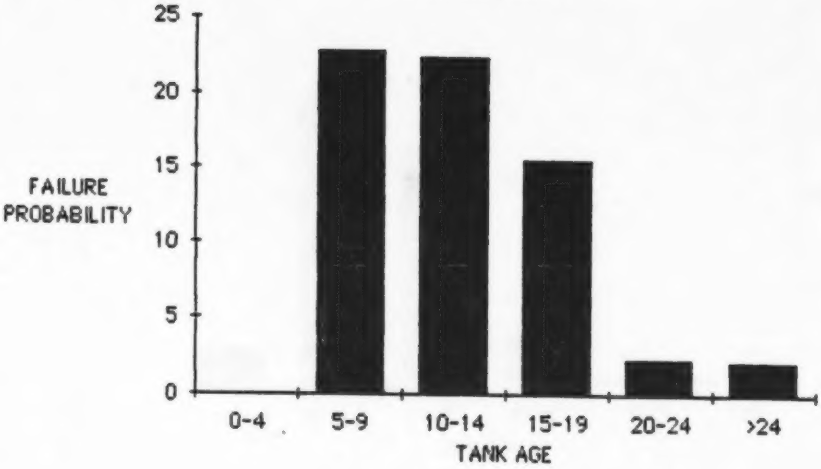
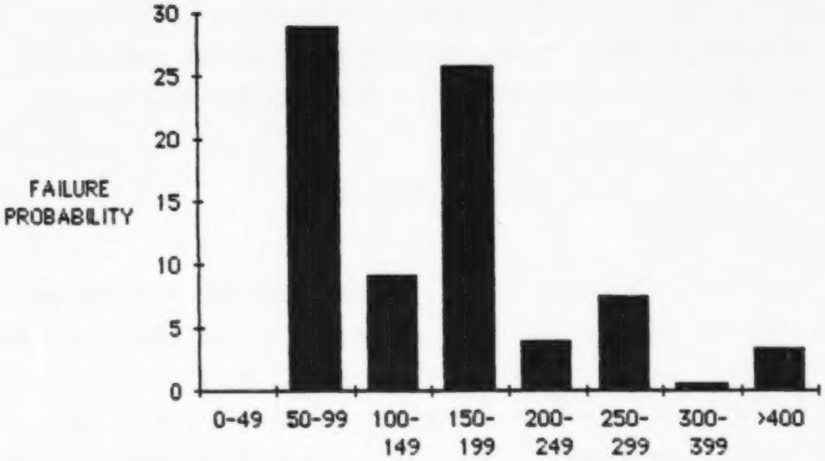


FIGURE 9
FAILURE PROBABILITY USING SAV X AGE



two dissimilar age distributions could easily produce the bimodal distribution depicted in Figure 9, even after the data have been converted from age categories to SAV x Age categories. It therefore appears that the data has greater usefulness if SAV and Age are both used as separated variables than it does if they are combined into the single variable of SAV x Age.

This analysis, however, does not indicate whether two or three SAV categories are preferable. This decision can be facilitated, though, by a re-examination of the raw data in Figures 1 and 2. These scatter diagrams indicate that a substantial percentage of the tanks, particularly leaking ones, are to be found between SAV=9 and SAV=11. There is no theoretical reason for dividing aggressive soils from benign soils at an SAV of either 9, 10, or 11, yet because of the clustering of the data, this arbitrary division can significantly alter the probability density functions when only two SAV categories are used. Thus, the natural clustering of the data favors the use of three SAV categories, and therefore three such categories will be used in the computer model.

COMPUTER MODELING

In order to carry out the Monte Carlo simulation on a year-by-year basis, it is necessary to calculate failure probabilities for each year between 1 and 20. This can most conveniently be done by straight-line interpolation between the age brackets used in Table 24. The results are presented in Tables 25 and 26. (Table 25 presents cumulative probabilities, while Table 26 presents probability densities). Once SAV is determined, these tables can then be used to determine annual probabilities of failure.

SAV can be determined in one of two ways: it can either be postulated as an exogenous parameter, or it can be determined stochastically. The deterministic approach is the simplest, and is to be preferred for the initial simulations, but the stochastic approach may be useful for modeling more complex scenarios.

The PACE data can be used to obtain a distribution of SAV's for the 300 tanks covered by the survey. This distribution is presented in Table 27.

While there is no guarantee that this distribution is representative of U.S. soils, it is probably a reasonable approximation, and it can be used to calcu-

TABLE 25. CUMULATIVE PROBABILITIES OF FAILURE IN LOW-, MEDIUM-, AND HIGH-SAV SOILS

	Cumulative Failure Probability (%)		
Tank Age	Low SAV (0-6)	Medium SAV (7-12)	High SAV (≥ 13)
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	2.22	5.34
6	0	4.44	10.68
7	0	6.66	16.02
8	0	8.88	21.36
9	0	11.10	26.70
10	1.26	14.70	31.34
11	2.52	18.30	35.98
12	3.78	21.90	40.62
13	5.04	25.50	45.26
14	6.30	29.10	49.90
15	9.84	34.08	55.22
16	13.38	39.06	60.54
17	16.92	44.04	65.86
18	20.46	49.02	71.18
19	24.00	54.00	76.50
20	28.86	56.66	77.18

TABLE 26. PROBABILITY DENSITIES FOR FAILURE IN LOW-, MEDIUM-, AND HIGH-SAV SOILS

	Probability Density (%)		
Tank Age	Low SAV (0-6)	Medium SAV (7-12)	High SAV (> 13)
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	2.22	5.34
6	0	2.22	5.34
7	0	2.22	5.34
8	0	2.22	5.34
9	0	2.22	5.34
10	1.26	3.60	4.64
11	1.26	3.60	4.64
12	1.26	3.60	4.64
13	1.26	3.60	4.64
14	1.26	3.60	4.64
15	3.54	4.98	5.32
16	3.54	4.98	5.32
17	3.54	4.98	5.32
18	3.54	4.98	5.32
19	3.54	4.98	5.32
20	4.86	2.66	0.68

TABLE 27. DISTRIBUTION OF SOIL AGGRESSIVENESS VALUES

SAV	Number of Tanks	Probability Density	Cumulative Probability (%)
1	0	0	0
2	20	6.7	6.7
3	7	2.3	9.0
4	10	3.3	12.3
5	21	7.0	19.3
6	16	5.3	24.7
7	10	3.3	28.0
8	7	2.3	30.3
9	34	11.3	41.7
10	43	14.3	56.0
11	12	4.0	60.0
12	35	11.7	71.7
13	22	7.3	79.0
14	20	6.7	85.7
15	7	2.3	88.0
16	28	9.3	97.3
17	6	2.0	99.3
18	1	.3	99.7
19	0	0	99.7
20	0	0	99.7
21	1	.3	100.0

TABLE 28. CONDITIONAL SAV DISTRIBUTION UNDER A REQUIREMENT THAT SAV NOT EXCEED 10

SAV	Probability Density (%)	Cumulative Probability (%)
1	0	0
2	11.9	11.9
3	4.2	16.1
4	5.9	22.0
5	12.5	34.5
6	9.5	44.0
7	5.9	50.0
8	4.2	54.1
9	20.2	74.4
10	25.6	100.0

late the probability that any given tank falls into each of the three SAV categories used in Tables 25 and 26. In addition, the SAV distribution can be used to obtain the conditional SAV-distribution under various regulatory scenarios. Consider, for example, a regulation requiring that SAV not exceed 10. If this regulation has no effect on the distribution of acceptable SAV's, then the conditional SAV distribution can be obtained simply by dividing the numbers in Table 27 by 56% (the unconditional probability that SAV $\leq$ 10). The results are presented in Table 28.

Similar computations could be undertaken for any other SAV cut-off. These results could then be used to determine the probability that the tank falls in each of the three SAV-categories used to predict the probability of failure.

More complex regulatory scenarios could also be modeled under this approach. For example, a proposed regulation might make the use of cathodic protection or secondary containment dependent on the aggressiveness of the soil in question. This could be modeled by first sampling a value for SAV and then using that value to determine other system parameters. Such a scenario is considerably more complicated than the scenarios that have been modeled to date, but if it is desired that such composite scenarios be studied, they are well within the capabilities of the model.

APPENDIX C

TANK FAILURE CASE STUDIES

TANK FAILURE CASE STUDY #1

SITE: Transformer manufacturing plant of Federal Pioneer Ltd

LOCATION: Regina, Saskatchewan, Canada

RELEASE MECHANISM: Pipe rupture

DATA SOURCE

- "A Case Study of a Spill of Industrial Chemicals: Polychlorinated Biphenyls and Chlorinated Benzenes," National Research Council Canada, NRCC No. 17586, 1980.

DESCRIPTION OF RELEASE

- In mid-1976 an underground pipe carrying PCB's from a 31,000 liter tank ruptured.

CAUSE OF RELEASE: Underground pipe ruptured

RELEASE MATERIALS

- How Detected:
- Material Types: PCB's (70%), chlorobenzenes (30%)
- Quantities Released: 6800 - 21,000 liters

RELEASE DURATION

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: land
- Description of contamination: underground

COMMENTS

- Additional information on this site can be found in:
  - Roberts, Russell J., John A. Cherry, Franklin W. Schwartz, "A Case Study of a Chemical Spill: Polychlorinated Biphenyl, (PCB's)--1. History, Distribution, and Surface Translocation," in Water Resources Research, Vol. 18, No. 3, pp. 525-534, June 1982.

- Roberts, Russell J., John A. Cherry, Franklin W. Schwartz, "A Case Study of a Chemical Spill: Polychlorinated Biphenyls (PCB's)--2. Hydrological Conditions and Containment Migration," in Water Resource Research, Vol. 18, No. 3, pp. 535-545, June 1982.

TANK FAILURE CASE STUDY #2

SITE: Unknown

LOCATION: Unknown

RELEASE MECHANISM: Catastrohic release

DATA SOURCE

- Dartnell Jr., R.C., T.A. Ventrone, "Explosion of a Para-Nitro-Meta-Cresol Unit," Chemical Engineering Progress, Vol. 67, No. 6, pp. 58-61.

DESCRIPTION OF RELEASE

- A temperature indicator on the feed-tank indicated a temperature of 154° C for the entire holding period up to the time of explosion. This was also the temperature of the product leaving the process step immediately upstream. Prior to the explosion, the pressure on the feed tank increased from 40 to 100%. No product was being fed.

CAUSE OF RELEASE: Explosion

RELEASE MATERIALS

- How Detected: pressure sensor
- Material Types: para-nitro-meta-cresol (PNMC)
- Quantities Released: 1500 gallons

RELEASE DURATION

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage
- Equipment Material: stainless steel

TANK FAILURE CASE STUDY #3

SITE: Unknown

LOCATION: Unknown

RELEASE MECHANISM: Unknown, probably tank corrosion

DATA SOURCE

- Eagen Jr., H.B., et al. "Removal of Hazardous Fluid from the Groundwater in a Congested Area--A Case History," Control of Hazardous Material Spills, Proceedings of 1976 National Conference on Controls of Hazardous Material Spills.

DESCRIPTION OF RELEASE

- Hydrocarbon migrated through the top of a shallow water table. It seeped at the land surface in low lying areas discharging 200 gallons per day into a perennial stream. Domestic wells were abandoned and product seeped into sewer lines.

CAUSE OF RELEASE: Unknown

RELEASE MATERIALS

- How Detected:
- Material Types: Hydrocarbon product (80% gasoline)
- Quantities Released: 500,000 gallons

RELEASE DURATION "long period of time"

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: water
- Description of contamination: underground into groundwater and from groundwater into surface water

COMMENTS

- This paper deals mostly with recovery operations and doesn't describe the failure event very well.

TANK FAILURE CASE STUDY #5

SITE: Bulk Terminals, tank storage farm

LOCATION Calumet Harbor Area, Chicago, Illinois

RELEASE MECHANISM: Pipe rupture

DATA SOURCE

- Hampson, T.R. "Chemical Leak at a Bulk Terminals Tank Farm," Control of Hazardous Material Spills, Proceedings of 1976 National Conference on Control of Hazardous Material Spills

DESCRIPTION OF RELEASE

- Silicon tetrachloride leaked from a pipe rupture, forming an acid cloud with the moist air. A rain storm worsened the situation, causing such dense fumes that electrical lines and transformers corroded and failed.

CAUSE OF RELEASE

- A block valve on an inlet line and a pressure relief valve were inadvertently closed. Pressure in the line began to build up. At about 12:30 p.m. on April 26, 1974, a flexible coupling on the inlet line burst under the pressure. The entire piping system shifted and a second line also cracked.

RELEASE MATERIALS

- How Detected: fumes
- Material Types: silicon tetrachloride
- Quantities Released: plume contained 40 ppm of HCl; 284,000 gallons were leaked; initially the acid cloud was about .25 miles wide, 1000 to 1500 feet high, and 1 mile in length, but due to the storm, it grew to 9 miles in length.

RELEASE DURATION

- It was 2.5 to 3 days before leak was sealed. However, 7 days passed before there was no threat of additional releases.

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage, steel tank with dry air or nitrogen padding equipment, capacity of 1,500,000 gallons. The tank contained 750,000 gallons of fluid.
- Tank/Treatment Components, Ancillary Equipment: extra automatic pressure vents, special valves, and closed transfer pumps.
- Equipment That Failed: flexible coupling, piping system, tank
- Dikes/Berms: present, they contained the liquid spill.

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: air and land
- Description of contamination: silicon tetrachloride poured out of tank into diked area and reacted vigorously with water in the air and rainfall to form HCl vapor. The enormous acid cloud spread over the far south side of the city.

COMMENTS

- Additional information on this site is located under:
  - Hoyle, W.C. and Melvin, G.L. "A Toxic Substance Leak in Retrospect: Prevention and Response." Control of Hazardous Material Spills, Proceedings of 1976 National Conference on Control of Hazardous Material Spills.

TANK FAILURE CASE STUDY #6

SITE: Service station

LOCATION: Cresskill, New Jersey

RELEASE MECHANISM: Tank corrosion

DATE SOURCE

- Kramer, William H. "Ground-water Pollution from Gasoline," GWMR, Spring 1982, pp. 18-22.

CAUSE OF RELEASE: Leaks in four 4000-gallon steel tanks due to corrosion.

RELEASE MATERIALS

- How Detected: routine inventory check
- Material Types: gasoline
- Quantities Released: 1200 gallons

RELEASE DURATION two or three days

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: gasoline storage for service station
- Equipment That Failed: tank
- Equipment Material: steel
- Equipment Age: 17 years

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: land
- Description of contamination: Underground

COMMENTS

- The article is very detailed; it indicates how the gasoline was recovered and the cost of recovery.

TANK FAILURE CASE STUDY #7

SITE: Unknown

LOCATION: Unknown

RELEASE MECHANISM: Interior tank corrosion

DATA SOURCE

- Bosich, Joseph F. Corrosion Prevention for Practicing Engineers, Barnes and Noble, Inc. New York, 1970, p. 186.

DESCRIPTION OF RELEASE

CAUSE OF RELEASE

- A workman accidentally dropped a 1" diameter hexagon-shaped nut to the bottom of the tank, causing localized interior corrosion.

RELEASE MATERIALS

- How Detected: visual detection
- Material Types: concentrated sulfuric acid
- Quantities Released: Unknown

RELEASE DURATION

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage
- Equipment Material: steel

TANK FAILURE CASE STUDY #8

SITE: Unknown

LOCATION: Sussex, Wisconsin

RELEASE MECHANISM: Unknown, probably tank corrosion

DATA SOURCE

- Lindoff, David E., Keros Cartwright, Groundwater Contamination: Problems and Remedial Actions, Environmental Geology Notes, Illinois State Geological Survey, May 1977, No. 81, Case history 88, p. 50.

DESCRIPTION OF RELEASE

CAUSE OF RELEASE

RELEASE MATERIALS

- How Detected: complaints that water from some wells tasted and smelled like petroleum
- Material Types: petroleum products
- Quantities Released:

RELEASE DURATION

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage

RELEASE ENVIRONMENT

- Description of contamination: surficial material, surface water, and probably groundwater

TANK FAILURE CASE STUDY #9

SITE: Unknown

LOCATION: Spring Mills, Pennsylvania

RELEASE MECHANISM: Unknown, probably corrosion or rupture

DATA SOURCE

- Lindoff, David E., Keros Cartwright, Ground-Water Contamination: Problems and Remedial Actions, Environmental Geology Notes, Illinois State Geological Survey, May 1977, No. 81, Case History 24, p. 30.

DESCRIPTION OF RELEASE

CAUSE OF RELEASE: Storage tank leak

RELEASE MATERIALS

- How Detected: explosion
- Material Types: gasoline
- Quantities Released: 200-250 gallons

RELEASE DURATION: 2 weeks

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: water
- Description of contamination: groundwater

TANK FAILURE CASE STUDY #10

SITE: Unknown

LOCATION: Southeastern Pennsylvania

RELEASE MECHANISM: Unknown, probably tank corrosion

DATA SOURCE

- Lindoff, David E., Keros Cartwright, Ground-Water Contamination: Probems and Remedial Actions, Environmental Geology Notes, Illinois State Geology Survey, May 1977, No. 81, p. 35, Case History 19.

DESCRIPTION OF RELEASE

CAUSE OF RELEASE: Leak in buried 10,000-gallon tank

RELEASE MATERIALS

- How Detected: appeared in a stream
- Material Types: fuel oil
- Quantities Released: 60,000 gallons

RELEASE DURATION

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: water
- Description of contamination: surface and groundwater

TANK FAILURE CASE STUDY #11

SITE: Unknown

LOCATION: Unknown

RELEASE MECHANISM: Unknown, probably tank corrosion or rupture

DATA SOURCE

- Lindorff, David E., Cartwright, Keros; Ground-Water Contamination: Problems and Remedial Actions, Illinois State Geological Survey Environmental Geology Notes, May 1977, No. 81, case history 5, p. 32.

DESCRIPTION OF RELEASE

- A leak was discovered in a gasoline storage tank at a service stastion. Further investigation indicated that several thousand gallons of gasoline had been lost over a period of three weeks.

CAUSE OF RELEASE: Leak in storage tank

RELEASE MATERIALS

- How Detected: fumes in nearby houses
- Material Types: gasolines
- Quantities Released: several thousand gallons

RELEASE DURATION 3 weeks

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: groundwater, explosive concentrations of fumes in four houses
- Description of contamination:

TANK FAILURE CASE STUDY #12

SITE: Essex Industrial Chemicals, Inc. chemical processing plant

LOCATION: Baltimore, Maryland

RELEASE MECHANISM: Tank rupture

DATA SOURCE

- "News in Brief: Hazardous Materials," Hazardous Materials Intelligence Report, 30 December, 1983, pp. 3-4.

DESCRIPTION OF RELEASE: An outdoor storage tank burst

CAUSE OF RELEASE

RELEASE MATERIALS

- How Detected: storage tank burst
- Material Types: sulfuric acid
- Quantities Released: 485,000 gallons

RELEASE DURATION

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown:
- Description of contamination: approximately 388,000 gallons traveled over the frozen ground at the plant and spilled into the Cabin Branch waterway, which leads into Curtis Creek and eventually into the Chesapeake Bay.

TANK FAILURE CASE STUDY #13

SITE: Allied Chemical Corporation

LOCATION: Louisiana

RELEASE MECHANISM: Tank rupture

DATA SOURCE

- Shields, Edward, Dessert, W.J., "Learning a Lesson from a Sulfuric Acid Tank Failure," Pollution Engineering, December 1981, pp. 39-40.

DESCRIPTION OF RELEASE: Into the ground

CAUSE OF RELEASE

- An inlet nozzle for the addition of acid to the tank was located too close to the tank wall. The cast iron inlet pipe broke due to corrosion and the high velocity of the incoming acid stripped the protective coating on the sides of the tank. Eventually the tank ruptured.

RELEASE MATERIALS

- How Detected: rupture in tank
- Material Types: 93% sulfuric acid
- Quantities Released: 2500 tons

RELEASE DURATION: 625 minutes (10.4 hours)

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage
- Tank/Treatment Components, Ancillary Equipment: outlet fittings, inlet nozzle manhole
- Equipment That Failed: vertical weld
- Equipment Material: A-283 grade C steel plate
- Equipment Age: Unknown
- Corrosion Protection: ferrous sulfate film

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown:
- Description of contamination: effluent discharge pumps to Mississippi River were turned off and the rain water drainage pipe from the tank farm impoundment area was sealed.

COMMENTS

- A 3000-ton sulfric acid tank in southern Canada also failed because the inlet nozzle was too close to the tank wall.

TANK FAILURE CASE STUDY #14

SITE: Unknown

LOCATION: Unknown

RELEASE MECHANISM: Pipe rupture

DATA SOURCE

- Vervalin, Charles H., "Learn from HPI plant fires," Hydrocarbon Processing

DESCRIPTION OF RELEASE

- About 1000 gallons of the hydrocarbon mixture flowed through a 3/8" pipe opening in the pump housing from which the pipe plug had fallen. Most was absorbed by the ground, however some flowed about 50 feet from the tank through a shallow ditch.

CAUSE OF RELEASE

- A pipe plug had fallen or had been blown. The plug was non-metallic.

RELEASE MATERIALS

- How Detected: fire
- Material Types: hydrocarbon mixture of cyclohexane and n-heptane
- Quantities Released: 1000 gallons

RELEASE DURATION

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: land
- Description of contamination: The leaking fluid was absorbed by the ground. Some of it flowed about 50 feet from the tank to a shallow ditch.

TANK FAILURE CASE STUDY #15

SITE: Tank farm of General American Transportation Co.

LOCATION: San Pedro, California

RELEASE MECHANISM: Pipe rupture

DATA SOURCE

- Vervalin, Charles H., "Learn from HPI Plant Fires," Hydrocarbon Processing, December 1972, pp. 49-50.

DESCRIPTION OF RELEASE

- A tank truck collided with a pipe, and fire engulfed the tank and truck. The fire spread to nearby trucks.

CAUSE OF RELEASE

- A tank truck apparently sheared a pipe leading to a 30,000 gallon tank.

RELEASE MATERIALS

- How Detected: fire
- Material Types: vinyl acetate
- Quantities Released: 30,000 gallons

RELEASE DURATION

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage
- Equipment That Failed: pipe
- Dikes/Berms: diked area around tank farm

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: land
- Description of contamination:

TANK FAILURE CASE STUDY #16

SITE: Oil processing and reclamation facility, Bridgeport Rental and Oil Services

LOCATION: Southern New Jersey

RELEASE MECHANISM: Tank corrosion

DATA SOURCE

- Whittaker, Kenneth T., Goltz, Robert, "Cost Effective Management of an Abandoned Hazardous Waste Site by a Staged Clean-up Approach," Management of Uncontrolled Hazardous Waste Sites, 1982, pp. 262.

DESCRIPTION OF RELEASE

CAUSE OF RELEASE: Tank corrosion

RELEASE MATERIALS

- How Detected:
- Material Types: uncharacterized hydrocarbons, various benzene and phenolic polyaromatic hydrocarbons (phenanthene, napthalene) lagoon surface -- high concentration of solvents and PCBs
- Quantities Released: 5 of the 88 on-site 300,000-gallon tanks were empty

RELEASE DURATION

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: water (surface and groundwater)
- Description of contamination:

TANK FAILURE CASE STUDY #17

SITE: An electronic components manufacturing plant

LOCATION: A suburban area adjacent to a major city. The site is surrounded by residential neighborhoods and small farms.

RELEASE MECHANISM: Unknown, presumably tank corrosion

DATA SOURCE

- Assessment of the Technical, Environmental and Safety Aspects of Storage of Hazardous Waste in Underground Tanks, Vol. I, SCS Engineers, Reston, Virginia, August 1983, pp. 3-36 - 3-46.

DESCRIPTION OF RELEASE

- Lack of inventory and/or environmental monitoring, tank inspection, or tank testing programs at this site allowed a waste solvent storage tank leak to go undetected for approximately 1½ years. The leak material contaminated soil and ground water. As a result of the duration and size of the leak and the hydrogeology of the site, transport of the contamination into three aquifers and over an area of about 1/3 square mile occurred.

CAUSE OF RELEASE

RELEASE MATERIALS

- How Detected: a mass balance analysis on the solvents entering and exiting the plant disclosed a leaking tank
- Material Types: solvents - Acetone, 1-1-Dichloroethylene, Freon 113, Isopropyl alcohol, 1.1.1-Trichloroethane, and Xylene
- Quantities Released: 58,000 gallons

RELEASE DURATION 1½ years

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: land
- Description of contamination:

TANK FAILURE CASE STUDY #18

SITE: A manufacturing plant that produces electronic computing equipment, semi-conductors and related devices.

LOCATION: A suburban area adjacent to a major city and is surrounded by residential neighborhoods, small farms, a hospital, and a golf course.

RELEASE MECHANISM: Unknown, but includes a corroded pipe

DATA SOURCE

- Assessment of the Technical, Environmental and Safety Aspects of Storage of Hazardous Waste in Underground Tanks, Vol. I, SCS Engineers, Reston, Virginia, August 1983, pp. 3-47 - 3-64.

DESCRIPTION OF RELEASE

CAUSE OF RELEASE

- Some of the probable causes are improper disposal of the chemicals, past operational problems, and a corroded drainline, but most of the causes are unknown.

RELEASE MATERIALS

- How Detected: unknown
- Material Types: solvent (acetone; ethyl amyl ketone; Freon 113; isopropyl alcohol; 1,1,1-trichloroethane; 1,1,1-trichloroethylene; or Xylene)
- Quantities Released:

RELEASE DURATION

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: storage, treatment, sumps
- Equipment Material: concrete, fiberglass, carbon steel, stainless steel

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: land
- Description of contamination:

COMMENTS

- Lack of inventory and/or environmental monitoring, tank inspection or tank testing programs at this site allowed many leaks to go undetected for as long as 11 years before detection. The source of pollution has been determined for only one of the three areas found to have soil and groundwater contamination. Transport of the released chemicals into three aquifers for over a mile away from the site resulted from the duration and size of the leaks and the hydrogeology of the area.

- This appears to be the same site as the one discussed in the preceding case study, but this incident apparently involves a separate set of failures.

TANK FAILURE CASE STUDY #19

SITE: Agricultural chemical manufacturing plant

LOCATION: Northern California

DATE SOURCE

- United States Environmental Protection Agency, Case Studies 1-23: Remedial Response at Hazardous Waste Sites, EPA-540/2-84-0026, March 1984 (Case Study #2).

RELEASE MECHANISM

- Pipe corrosion or rupture, accidental pills, and tank corrosion or rupture.

DESCRIPTION OF RELEASE

- The tanks in question were part of the treatment system for rainfall run-off and rinsewater from the plant's chemical handling areas. 15,000 gallons leaked from an underground "skimmer tank." There were also a number of small-scale chemical spills, and leakage from 2 joints in a 300' chemical drain used to connect parts of the system.

CAUSES OF RELEASE: Unknown, but probably include corrosion or rupture of both the tank and the drain.

RELEASE MATERIALS

- How Detected: "Foul taste" in nearby drinking wells.
- Material Types: Toluene and various herbicides.
- Quantities Released: In excess of 15,000 gallons.

RELEASE DURATION

- Unknown. The system was constructed in 1971; the leak was discovered in 1979.

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: land
- Description of contamination: There was contamination of shallow groundwater. Nearby drinking wells had a "foul taste," but no detectable chemicals.

TANK FAILURE CASE STUDY #20

SITE: Biocraft Laboratories

LOCATION: Waldwick, NJ

RELEASE MECHANISM: Gasket leak

DATA SOURCE:

- United States Environmental Protection Agency, Case Studies 1-23: Remedial Response at Hazardous Waste Sites, EPA-540/2-84-0026, March 1984 (Case Study #4).

DESCRIPTION OF RELEASE

- A gasket in a fill pipe for an underground storage tank disintegrated due to incompatibility with the waste.

CAUSE OF RELEASE

- Incompatibility between gasket and waste

RELEASE MATERIALS

- How Detected: Groundwater testing
- Material Types: Methylene chloride, N-butyl alcohol, dimethyl aniline, acetone, and a variety of trace organics.
- Quantities released: Uncertain--possibly as much as 360,000 lbs.

RELEASE DURATION: Probably 3 years

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank use: storage
- Equipment that failed: gasket
- Tank design: steel tank with no secondary containment and apparently no corrosion protection
- Age of system: new (constructed in 1972, failure detected in 1975)

RELEASE ENVIRONMENT:

- Land, Water, Air, Unknown: land
- Extent of contamination: Groundwater was contaminated. The release was also the probable cause of a fish kill in a nearby stream in 1973.

TANK FAILURE CASE STUDY #21

SITE: General Electric transformer manufacturing and repair facility

LOCATION: Oakland, CA

RELEASE MECHANISM: Accidental spills, overflows, and tank rupture

DATA SOURCE:

- United States Environmental Protection Agency, Case Studies 1-23: Remedial Response at Hazardous Waste Sites, EPA-540/,2-84-0026, March 1984 (Case Study #9).

DESCRIPTION OF RELEASE

- Over the operating history of the plant, a number of spills had occurred (a) at an above-ground tank farm used for a petroleum-based thinner and oil; (b) near two above-ground 5,000-gallon tanks used for Pyranol (contains PCB); (c) in the area where rail tank cars were unloaded by pumping; (d) possibly due to minor leakage from oil-warming operations inside the building; and (e) from a mobile filtering unit that would occasionally "blow" from too much pressure.

  Additional contamination came from trench burial of liquid PCB's and contaminated solids such as dialectric paper, and from continued discharges from a lab sink following the collapse of a septic tank (date of collapse is unknown. Discharges continued until the mid 1960's).

CAUSES OF RELEASE

- Above-ground spills
- Overflows
- Tank rupture

RELEASE MATERIALS

- How detected:
- Material types: Hydrocarbon products and PCB-contaminated oils
- Quantities released: 20,000 gallons

RELEASE DURATION: Miscellaneous spills between 1927 and 1975.

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: land
- Description of contamination: surface spills and underground leaks. There was widespread contamination of on-site soils and groundwater.

TANK FAILURE CASE STUDY #22

SITE: Houston Chemical Company

LOCATION: Houston, MO.

RELEASE MECHANISM: Tank rupture and pipe design error

DATE SOURCE

- United States Environmental Protection Agency, Case Studies 1-23: Remedial Response at Hazardous Waste Sites, EPA-540/2-84-0026, March 1984 (Case Study #13).

DESCRIPTION OF RELEASE

- The tank was a 21,000-gallon, steel, horizontal, above-ground storage tank. There was no containment system. It collapsed for several reasons:
  - The saddle support blocks were not sufficient either in spacing or number.
  - There were weaknesses due to corrosion and previous abuse.
  - The saddle support blocks were not engineered to fit the curvature of the tank.
  - A drain pipe and valve were installed on the underside of tank. When the tank collapsed, the drain control valve and piping sheared off. This was a design error.

An overflow pit contained 5% of the spill. The remainder bypassed the pit due to the absence of suitable dikes. The oil flowed into a roadside ditch, under a culvert and into a catch basin where it remained temporarily. It then infiltrated the ground, reappearing 125' downgradient. Eventually it flowed into a farm pond where the water level was low enough that it remained.

The initial report was not received by EPA until 4 days after the spill. That report falsely stated that the spill had been contained by a dike and that clean-up was under way. The volume of the spill was initially reported as 10,000 gal.

RELEASE MATERIALS

- How Detected:
- Material Types: 5% solution of PCP in diesel oil.
- Quantities released: 15,000 gal.

RELEASE DURATION: Release occurred on June 14, 1979.

TANK DESIGN AND OPERATING CHARACTERISTICS

- Tank Use: Storage
- Tank Design: 21,000-gallon, steel, horizontal, above-ground, on cradles.
- Equipment that failed: cradles
- Secondary containment: present, but inadequate.

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: land and water
- Description of Contamination: There was a total fish kill in the farm pond and a threat of overflow into a navigatable river known as a valuable wildlife habitat. Soil along the path of flow was contaminated.

TANK FAILURE CASE STUDY #23

NAME: Howe, Inc.

LOCATION: Brooklyn Center, MN

RELEASE MECHANISM: Hazardous materials carried off-site by smoke from fire and run-off water from fire-fighting efforts.

DATE SOURCE

- United States Environmental Protection Agency, Case Studies 1-23: Remedial Response at Hazardous Waste Sites, EPA-540/2-84-0026, March 1984 (Case Study #14).

DESCRIPTION OF RELEASE

- In January, 1979, a fire occurred at a warehouse site containing 100 different pesticides totaling 80 tons of active ingredients. Water used to fight the fire flowed off-site, carrying with it dissolved pesticides and herbicides. Several additional dangers were involved:
  - Air pollution from combustion of organic solvents. Pigeons flying through the plume died immediately. Eleven fire fighters became ill.
  - Fallout from the plume.
  - Contaminated building debris.
  - Run-off from contaminated soils.

CAUSE OF RELEASE: Faulty acetylene torch

RELEASE MATERIALS

- How detected: immediate visual detection
- Material types: Pesticide- and herbicide-contaminated water; fumes.
- Quantities released: 500,000 gallons of contaminated water; unknown amount of fumes.

RELEASE DURATION: several hours

RELEASE ENVIRONMENTS

- Land, Water, Air, Unknown: land and air
- Description of contamination: Air and land surface. Because of cold temperatures, the contaminated water froze on the ground surface.

TANK FAILURE CASE STUDY #24

NAME: N. W. Mauthe, Inc.

LOCATION: Appleton, Wisconsin

RELEASE MECHANISM: Accidental spills; cracks in concrete floor.

DATA SOURCE

- United States Environmental Protection Agency, Case Studies 1-23: Remedial Response at Hazardous Waste Sites, EPA-540/2-84-0026, March 1984 (Case Study #16).

DESCRIPTION OF RELEASE

- A blower vent for a chrome-plating tank discharged chromium-laden mist to the outside;
- Drippings from chromating tanks were channeled to a sanitary sewer by a trough in the floor. Cracks in the trough and the concrete flooring led to seepage into underlying soil.

CAUSE OF RELEASE

- Poor design and aging of concrete floor

RELEASE MATERIALS

- How Detected: In March, 1982, yellow puddles were observed on adjacent property.
- Material Types: Chromium-contaminated water.
- Quantities released:

RELEASE DURATION

- The shop operated from 1966 through 1976. The releases were probably ongoing through much or all of that time.

RELEASE ENVIRONMENT

- Land, Water, Air, Unknown: land
- Description of contamination: Continuing spills contaminated soils at the site. The contaminants migrated off-site, where they were discovered as "yellow puddles." There was a threat to nearby residences and schools and a threat of run-off to storm sewers leading to the Fox River.

TANK FAILURE CASE STUDY #25

NAME: Quanta Resources

LOCATION: Queens, NY

RELEASE MECHANISM: Vandalism

DATA SOURCE

- United States Environmental Protection Agency, Case Studyes 1-23: Remedial Response at Hazardous Waste Sites, EPA - 540/2-84-0026, March 1984 (Case Study #19).

DESCRIPTION OF INCIDENT

- The facility was a processing facility containing about 500,000 gal. of miscellaneous wastes, including PCB-contaminated oils, cyanides, heavy metals, and low flash-point chlorinated solvents. Bankruptcy of the owner left the facility without security against arson or vandalism.

CAUSE OF RELEASE

- None--no release actually occurred. However, the unguarded state of the facility posed a substantial risk of arson or vandalism.

TANK FAILURE CASE STUDY #26

NAME: White's Septic Tank Services

LOCATION: DuPage County, IL

RELEASE MECHANISM: Operator error

DATA SOURCE

- Landfilling of Special and Hazardous Waste in Illinois: A Report to the Illinois General Assembly, Illinois Legislative Investigating Commission, 1977.

DESCRIPTION OF INCIDENT

- White operated a land treatment facility on his 30-acre farm. He was permitted to accept only domestic septage. He could spread it only in good weather and not near the river. Never- theless, he accepted commercial wastes of unknown nature, mixing them with the septage in his trucks. He professed ignorance of his permit requirements and was "cordial." His record-keeping was virtually non- existent. According to the report, he was "totally lacking in the skill, equipment, knowledge, and desire necessary [for] toxic waste disposal...--blythely spread [ing] industrial wastes over farm land."

COMMENTS

- White had also been in the same business at different times at other Illinois sites.
- This case study does not involve hazardous waste tanks. It is nevertheless relevant, because tank operators can be just as untrained as landfarm operators.

TANK FAILURE CASE STUDY #27

NAME: White's Septic Tank Services

LOCATION: DuPage County, IL

RELEASE MECHANISM: Inspection error

DATA SOURCE

- Landfilling of Special and Hazardous Waste in Illinois: A Report to the Illinois General Assembly, Illinois Legislative Investigating Commission, 1977.

DESCRIPTION OF INCIDENT (see preceding case study)

- An Illinois Department of Public Health inspector made a routine visit to White's landfarm on 7/6/78, accompanied by an Illinois Legislative Investigation Commission observer. The visit involved an application for license renewal. The IDPH inspector:
  - Was uncertain of what the law required;
  - Was unaware of the danger of leachate contaminating river;
  - Took no water samples;
  - Placed a checkmark next to "Inspection of servicing equipment" without ever going near the one truck that made a dump while he was on the site; and
  - Did not seem particularly knowledgeable about the operating requirements.

COMMENTS

- This case study does not involve hazardous waste tanks. It is nevertheless relevant, because similar inspection errors could occur at any type of hazardous waste facility.

TANK FAILURE CASE STUDY #28

NAME: Destructol Carolawn

LOCATION: Kernersville, NC

DATA SOURCE: EPA/SCS Remedial Action Cases, Site D

RELEASE MECHANISM: Catastrophic release (vandalism)

DESCRIPTION OF RELEASE

- On June 3, 1977, vandals opened the valves on six storage tanks at a commercial hazardous waste incinerator. There were no locks on the valves. There was no secondary containment.

RELEASE MATERIALS:

- How Detected: Immediate visual observation
- Material Types:
- Quantities Released: 30,000 gal.

RELEASE ENVIRONNMENT:

- Land, Water, Air, Unknown: land and water
- Description of contamination: There was a 90-99% fish kill in a nearby 50-acre reservoir. 200 local residents were temporarily evacuated. Temporary water rationing and industrial layoffs resulted, as the municipality sought an alternative water source. So far, there has been permanent loss of the reservoir as a drinking water source (the state refused to approve the reservoir as a drinking water source as long as the threat of future contamination remained).

DRAFT REPORT

HAZARDOUS WASTE
TANK FAILURE MODEL:
DESCRIPTION OF METHODOLOGY
APPENDIX D, E

Prepared for:

U.S. Environmental Protection Agency
Office of Solid Waste
Economic Analysis Branch
January 13, 1986

Submitted by:

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APPENDIX D

SYSTEM DESIGN CHARACTERISTICS

Batch Distillation

We model distillation as a batch process using two above-ground tanks.

If the first tank is larger than 1000 gallons, we assume that the waste is pumped into it at a rate of 100 gallons per minute. Otherwise we assume that the pumping rate is 25 gallons per minute. We set the batch volume equal to the operating capacity of the first tank, and the fill time equal to the batch volume divided by the pumping rate. The pressure in the inlet pipe and the pressure at the gasketed or welded flange are equal to the sum of the pump pressure and the static head from the fluid source. We assume that friction losses and kinetic losses are small compared to these values. In future versions of the model, however, we may decide to account for these losses.

The first tank in this process is the distillation tank. Its capacity is determined by user input, and we assume that its fluid depth is 80% of its height. We assume that distillation is completed in 4 hours. We assume that the volatile fraction flows out the top of the distillation tank at a constant rate equal to the tank's operating capacity multiplied by the fraction of the waste accounted for by the volatile constituent (determined by user input) multiplied by the treatment efficiency (determined by user input) divided by the four-hour retention time. We assume that the fluid is condensed at a location three feet higher than the tank which accumulates the distillate. Thus, there is a three-foot pressure head on the pipe and the flange connecting the distillation tank to the accumulation tank.

We assume that the accumulation tank is the same size as the distillation tank. Its operating level, retention time, and pressure head are the same as those for the distillation tank. We assume that there is no reflux of the distillate back into the still.

We calculate the transfer volume and transfer time for the accumulation tank's outlet pipe using the same pumping rate that we applied to the inlet pipe for the distillation tank. We assume that the pressure on the gasketed or welded outlet flange equals the static head created by the fluid in the accumulation tank, while pressure in the pipe also includes the pump pressure.

At the end of the distillation process, the still bottoms are pumped out the bottom of the distillation tank at the 100- or 25-gallon-per-minute pumping rate. The volume to be transferred equals the tank's operating capacity times the original fraction of non-volatile constituents plus the fraction of volatile constituent remaining after distillation. The transfer time equals the volume to be transfered divided by the pumping rate. The pressure head on the outlet flange equals the static head of the fluid in the distillation tank, while the pressure in the pipe also includes the pumping head.

Chrome Reduction/Precipitation

We model chrome reduction/precipitation as a continuous process using three above-ground or in-ground tanks. Minor modifications to the model will allow for a batch process to be selected.

The waste is pumped into the first tank at a rate that is equal to the operating capacity of the tank divided by the tank's retention time, which is the length of time the fluid is kept in the tank to complete any reactions or mixing processes. We assume that the waste has a thirty minute retention time in the first tank where the waste pH is adjusted to a pH between two and three. The pressures in the inlet pipe and the pressures at the inlet gasketed or welded flange are calculated in the same manner as the fill pipe for the first tank of the batch distillation process. Outlet flange pressures are equal to the static pressure from the fluid in the tank. We assume that the fluid is always pumped into the top of the tank and that fluid depth in each tank is 80% of its height.

The batch volume for a continuous process is defined as the daily volume throughput and the filling and discharge times for each piping section are set to the number of minutes in the operating day (operating hours per day is a user input).

We assume that the pH adjusted waste is pumped into the second tank at the same rate it is pumped into the first tank. In the second tank sulfur dioxide is added at a loading rate of 2 pounds of sulfur dioxide per pound of chromium (VI) in order to reduce chromium from chromium (VI) to chromium (III). The flocculation agent is added at a loading rate of 0.1 lb. polyelectrolyte per 1000 gallons of waste, thus giving a total retention time in the second tank of two hours. We assume that no reactions or phase changes occur in the reactor except for those pertaining to the destruction of the hazardous constituents. Also, we assume that destruction of the hazardous constituent from both dissolved and suspended portions occurs and that destruction products are non-hazardous. No appreciable volume change is assumed due to the addition of sulfur dioxide.

The reduced waste containing the flocculating agent is pumped into the third tank at the same rate that the waste is pumped into the first tank. In the third tank the clarifier requires a four hour retention time to clarify the waste. We assume that all of the dissolved hazardous constituents are removed to the suspended solids phase upon the addition of the flocculating agent. In order to maintain a high efficiency in the clarifier we assume that the clarifier does not receive waste streams that have a suspended solids content greater than two percent on a mass basis.

We assume that the effluent from the clarifier contains no suspended solids and that all suspended solids and all coagulant chemicals are carried out with the underflow waste stream, if the percent solids is less than or equal to two percent by mass. The discharge rates are assumed to be half of the fill rate. This is based on the assumption that the underflow waste stream is one percent solids by mass and that the inlet stream to the third tank is one-half percent solids by mass.

The constituent in the waste stream generates dry solids in the following ratios: 1.98 pounds dry solids per pound chromium (VI) precipitated, 2.89 pounds dry solids per pound aluminum precipitated, and 1.51 pounds dry solids per pound metal precipitated.

Cyanide Oxidation Precipitation

We model cyanide oxidation/precipitation as a continuous process using three above-ground or in-ground tanks. Minor modifications to the model will allow for a batch process to be selected.

The waste is pumped into the first tank at a rate that is equal to the operating capacity of the tank divided by the tank's retention time, which is the length of time the fluid is kept in the tank to complete any reactions or mixing processes. We assume that the waste has a thirty minute retention time in the first tank where the waste pH is adjusted to a pH between nine and ten. The pressures in the inlet pipe and the pressures at the inlet gasketed or welded flange are calculated in the same manner as the fill pipe for the first tank of the batch distillation process. Outlet flange pressures are equal to the static pressure from the fluid in the tank. We assume that the fluid is always pumped into the top of the tank and that fluid depth in each tank is 80% of its height.

The batch volume for a continuous process is defined as the daily volume throughput and the filling and discharge times for each piping section are set to the number of minutes in the operating day (operating hours per day is a user input).

We assume that the pH adjusted waste is pumped into the second tank at the same rate it is pumped into the first tank. In the second tank the waste is chlorinated at a loading rate of 8 parts chlorine to 1 part cyanide in order to oxidize the cyanide from free cyanide or cyanates to carbonates, nitrogen, and nitrous oxide. The flocculation agent is added at a loading rate of 0.1 lb. polyelectrolyte per 1000 gallons of waste, thus giving a total retention time in the second tank of two hours. We assume that no reactions or phase changes occur in the reactor except for those pertaining to the destruction of the hazardous constituents and that the heat of reaction in either tank is negligible. Also, we assume that destruction products formed in the second tank are non-hazardous. No appreciable volume change is assumed due to the addition of sulfur dioxide.

The oxidized waste containing the flocculating agent is pumped into the third tank at the same rate that the waste is pumped into the first tank. In the third tank the clarifier requires a four hour retention time to clarify the waste. We assume that all of the dissolved hazardous constituents are removed to the suspended solids phase upon the addition of the flocculating agent. In order to maintain a high efficiency in the clarifier we assume that the clarifier does not receive waste streams that have a suspended solids content greater than two percent on a mass basis.

We assume that the effluent from the clarifier contains no suspended solids and that all suspended solids and all coagulant chemicals are carried out with the underflow waste stream, if the percent solids is less than or equal to two percent by mass. The discharge rates are assumed to be half of the fill rate. This is based on the assumption that the underflow waste stream is one percent solids by mass and that the inlet stream to the third tank is one-half percent solids by mass.

The constituent in the waste stream generates dry solids in the following ratios: 1.98 pounds dry solids per pound chromium (VI) precipitated, 2.89 pounds dry solids per pound aluminum precipitated, and 1.51 pounds dry solids per pound metal precipitated.

Storage

For above-ground or in-ground storage tanks with a capacity of 1000 gallons or greater, we assume that the waste is pumped into it at a rate of 100 gallons per minute. Otherwise we assume that the pumping rate is 25 gallons per minute. For a batch process storage tank we set the batch volume equal to the tank capacity divided by the number of batches needed to fill the tank, and the fill time is equal to the batch volume divided by the pumping rate. The discharge volume is equal to the tank capacity. For a continuous process storage tank, the batch volume for this tank is defined as the daily volume throughput. The daily volume throughput is defined by dividing the annual throughput (a model input) by the number of days in the year. The filling and discharge times are set to the number of minutes in the operating day and the fill and discharge rates are calculated by dividing the daily volume throughput by the number of minutes in the day. The pressure in the inlet pipe and the pressure at the gasketed or welded flange are calculated in the same manner as the fill pipe for the first tank in the batch distillation process. We assume that the pressure on the outlet pipe and gasketed or welded flange equals the static head created by the fluid in the tank.

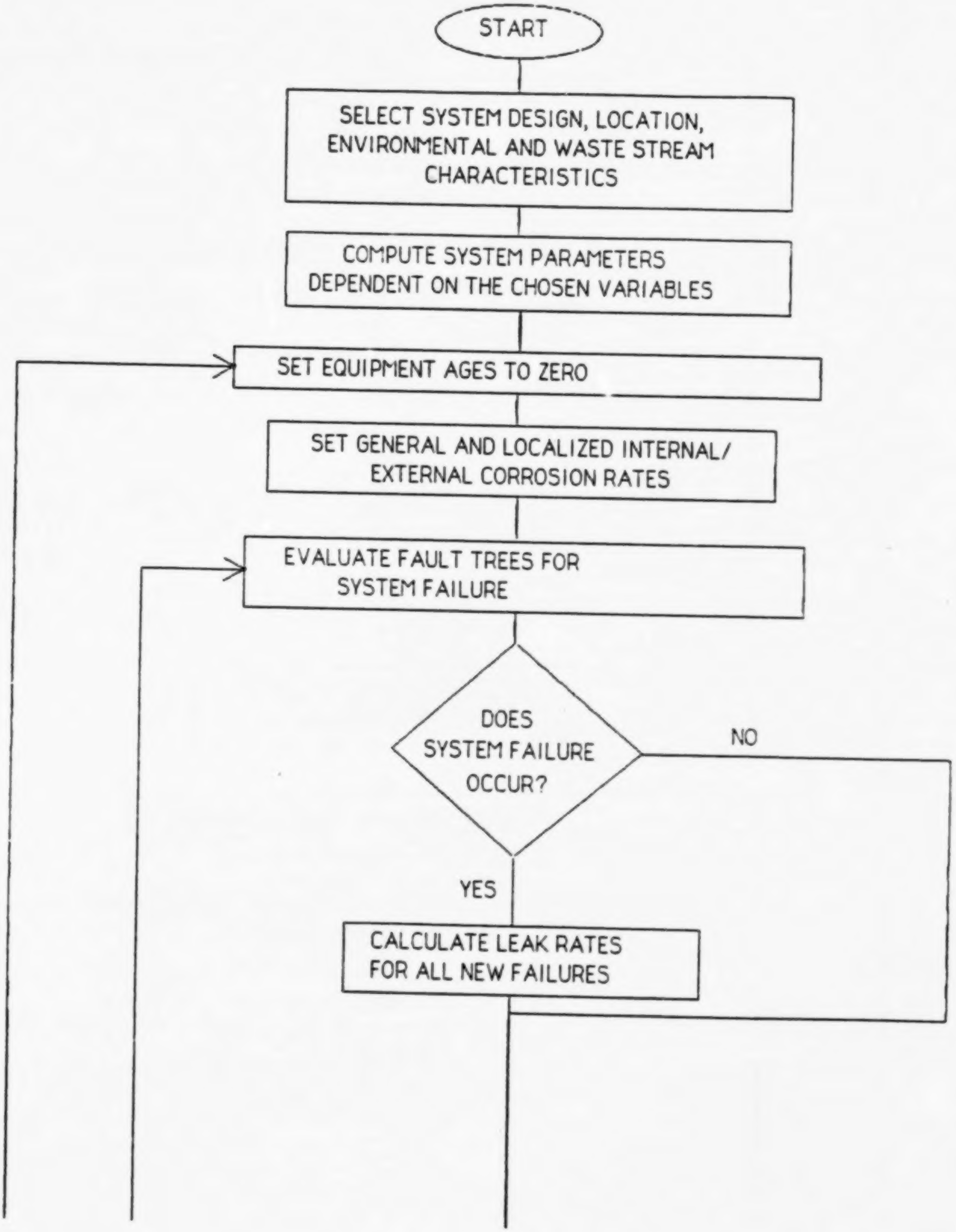
If the storage tank is underground the fill rate is determined by the standard gravitational flow equation. The batch volumes and fill times are calculated in the same manner as above-ground tanks. The pressure in the inlet pipe is assumed to be under eight feet of pressure at the midpoint of the pipe and ten feet of pressure at the gasketed or welded flange (assuming that the top of the tank is four feet from the surface). We assume four feet of pressure head from the midpoint of the pipe to the pump and that there are no outlet flange releases. This is because the fluid is not in contact with the flange since the outlet pipe extends to the bottom of the tank.

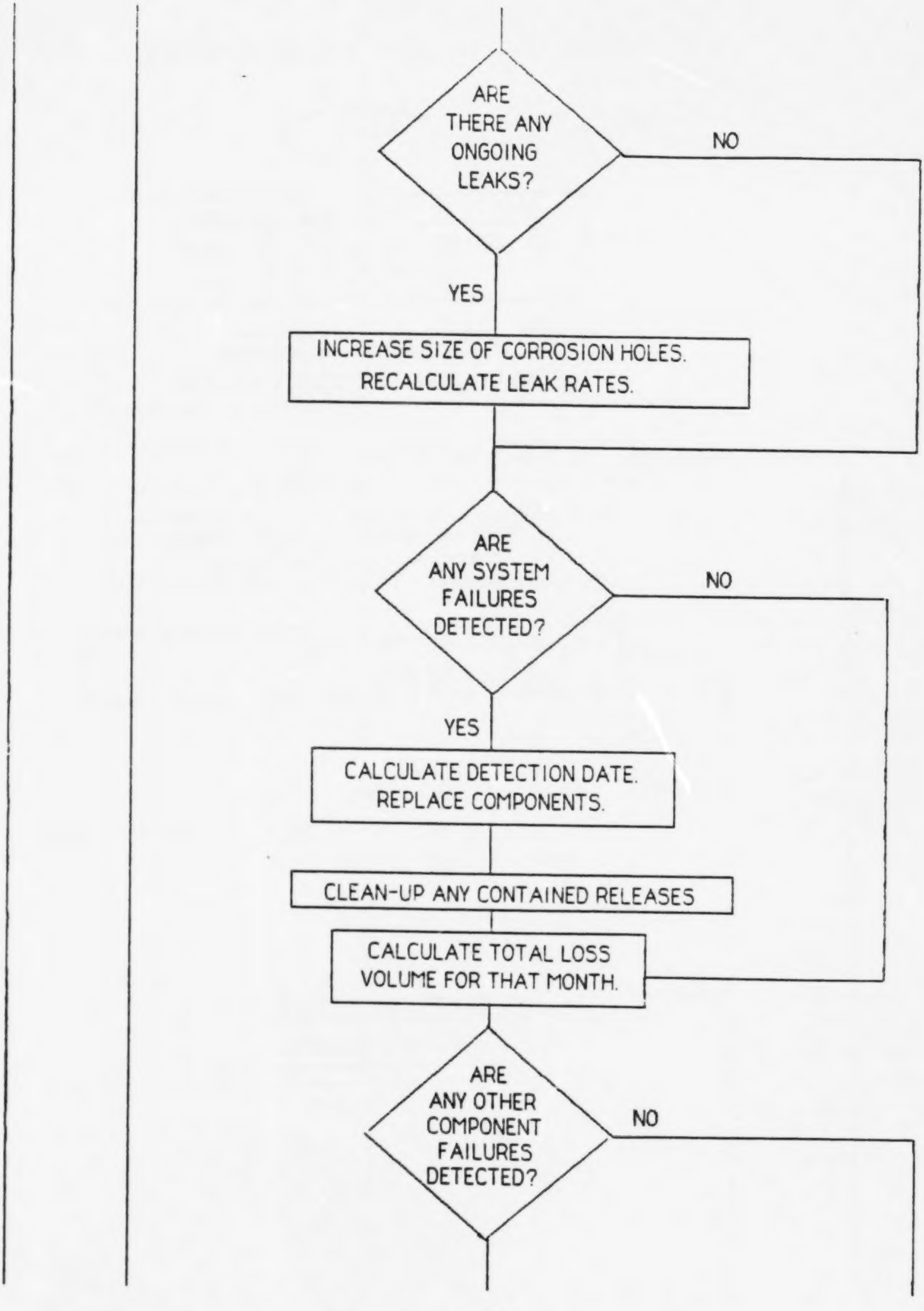
The tank's typical operating capacity is determined as a user input, and we assume that its fluid depth is 50% of the tank, thus setting the static pressure head of the fluid in the tank.

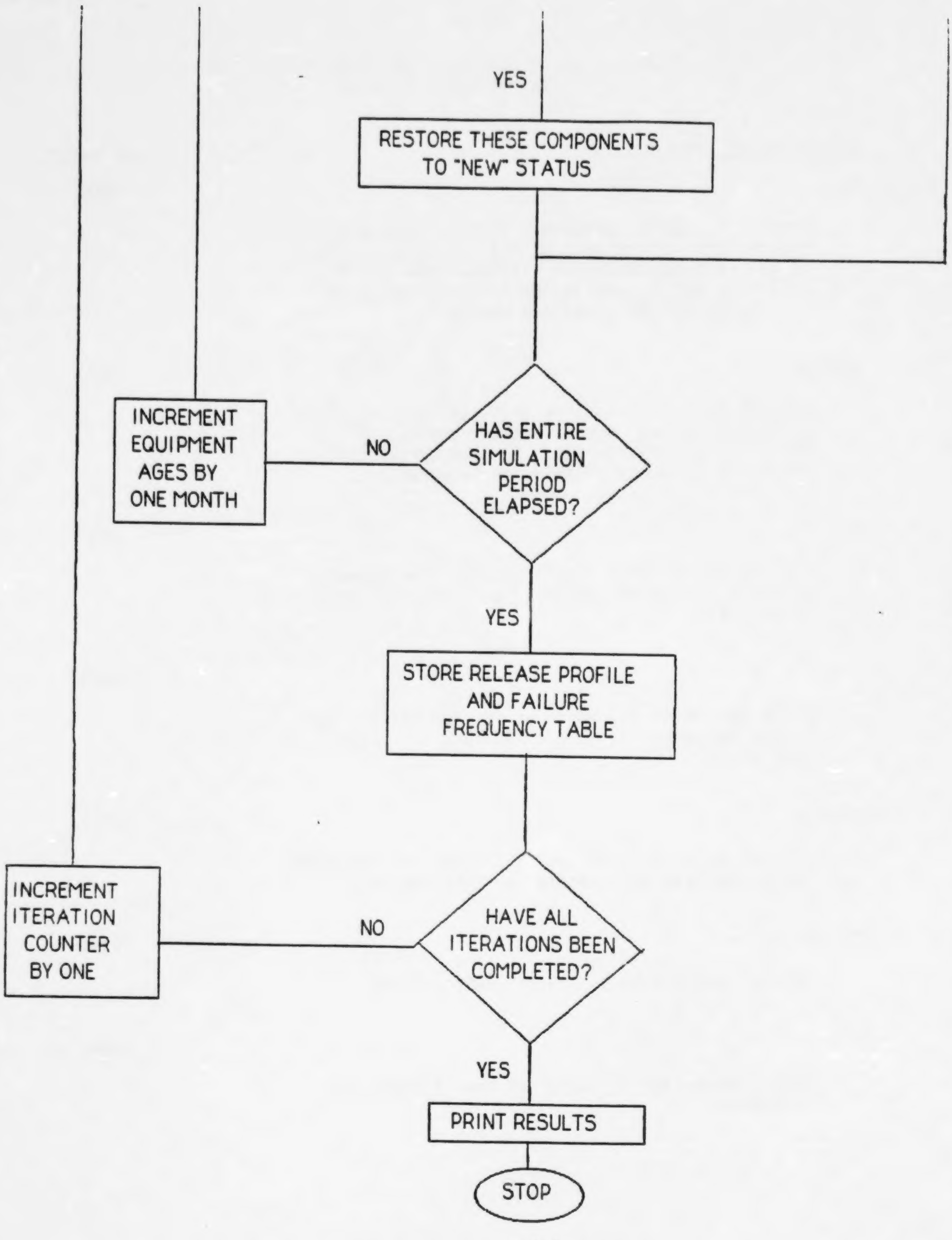
APPENDIX E

COMPUTER CODE FOR SIMULATION MODEL

FIGURE 17. FLOW CHART FOR SIMULATION MODEL


START
SELECT SYSTEM DESIGN, LOCATION, ENVIRONMENTAL AND WASTE STREAM CHARACTERISTICS
COMPUTE SYSTEM PARAMETERS DEPENDENT ON THE CHOSEN VARIABLES
SET EQUIPMENT AGES TO ZERO
SET GENERAL AND LOCALIZED INTERNAL/ EXTERNAL CORROSION RATES
EVALUATE FAULT TREES FOR SYSTEM FAILURE
DOES SYSTEM FAILURE OCCUR?
NO
YES
CALCULATE LEAK RATES FOR ALL NEW FAILURES


ARE THERE ANY ONGOING LEAKS?
NO
YES
INCREASE SIZE OF CORROSION HOLES. RECALCULATE LEAK RATES.
ARE ANY SYSTEM FAILURES DETECTED?
NO
YES
CALCULATE DETECTION DATE. REPLACE COMPONENTS.
CLEAN-UP ANY CONTAINED RELEASES
CALCULATE TOTAL LOSS VOLUME FOR THAT MONTH.
ARE ANY OTHER COMPONENT FAILURES DETECTED?
NO


YES
RESTORE THESE COMPONENTS TO "NEW" STATUS
INCREMENT EQUIPMENT AGES BY ONE MONTH
NO
HAS ENTIRE SIMULATION PERIOD ELAPSED?
YES
STORE RELEASE PROFILE AND FAILURE FREQUENCY TABLE
INCREMENT ITERATION COUNTER BY ONE
NO
HAVE ALL ITERATIONS BEEN COMPLETED?
YES
PRINT RESULTS
STOP

DESCRIPTIONS OF FUNCTIONS AND SUBROUTINES USED IN THE COMPUTER CODE

Subroutine or Function	Line Number
TREE TREE is the driver program. It reads the model inputs, initializes most of the variables, calls up the routines that will simulate tank system failures, and increments the facility age counter (in years) and the iteration counter.	00010
ANCILOS ANCILOS calls the routines that simulate ancillary equipment failures due to leaks, ruptures or installation deficiencies. It also checks for ancillary secondary containment failures.	13065
FNB FNB samples binomial distributions. The binomial probability must be specified when this function is called.	3385
FTIME FTIME determines the month of initial failure for events for which the year of failure has been determined.	13445
LEAKRUP LEAKRUP calls the routines that check for component leaks, ruptures or installation deficiencies.	13475
DEFINCT DEFICNT simulates installation deficiencies.	15350
SPILLS SPILLS determines if there has been a loose hose connection.	16960

TNKCONT 17050

TNKCONT simulates tank secondary containment failures. (This excludes double-walled steel tanks, which are handled in LEAKRUP, DEFICNT and INADSTR).

INADSTR 17745

INADSTR checks for failures due to corrosion.

TNKDIM 20005

TNKDIM calculates tank dimensions based on the system design selected.

CORERAT 20590

CORERAT calls the routines that estimate the interior generalized corrosion/erosion rate and the exterior generalized and localized corrosion rates.

CORER 21485

CORER estimates the interior generalized corrosion/ erosion rates.

EXTCOR 21895

EXTCOR estimates the exterior generalized and localized corrosion rates.

CORPRB 22145

CORPRB samples the incompatability/aging factor for gaskets.

INTCORR 22195

INTCORR determines the interior localized corrosion rate.

THLOSS 22640

THLOSS subtracts the interior and exterior rates from the component's wall thickness variables.

FNN 23000

FNN draws a value from any specified normal distribution.

FBNE 23060

FNBE draws a value from any specified beta distribution.

CATREL 23355

CATREL checks for catastrophic failures.

RUPTURE 23620

RUPTURE samples the rupture fault tree for component rupture.

OVERFLW 23985

OVERFLW is used each month to check for overflows.

RELEASE 24530

RELEASE sizes the failure event releases by sampling a leak rate for each failure event and sampling a time of detection. Corrosion leak rates grow every month and detection times are a function of the detection options selected, detection sampling frequencies, leak rates, and volume losses.

RATEDET 54355

RATEDET uses the release rate to determine if a leak is detected by casual visual inspection.

RAN 54480

RAN draws a random number between 0 and 1.

LEAKRT 54505

LEAKRT estimates above-ground release rates and calls the routine that estimates underground release rates.

CLENUP 54925

CLENUP calculates the total volume that was contained and cleaned up. Because they are cleaned up, these releases are not included in the annual release totals.

IMMINV 54960

IMMINV models detection by casual inventory monitoring.

UGRATE 55180

UGRATE estimates release rates for releases into the soil.

SETOPAR 55460

SETOPAR calculates filling and discharge rates, batch volumes, and filling and discharge durations.

FNU 56435

FNU draws a value from any specified uniform distribution.

SETCOST 56485

SETCOST calculates the dimensions of the excavation for an underground tank system. We use these dimensions to determine detection thresholds for U-tubes and Pollulert systems.

REPLAC 57140

REPLAC replaces detected failed components and resamples time-to-failure variables that are associated with these components (e.g. coating time of failure or cathodic protection system time of failure).

SETVAP 58090

SETVAP estimates the vapor transport times (the time it takes the vapor to reach the detection threshold concentration at a vapor well.

ERF 58275

ERF interpolates the error function. This is used to estimate vapor transport times.

VAPOR 58630

VAPOR checks for vapor sensor failure.

PENET 58760

PENET calculates the fluid's depth of penetration into the soil.

SAVCALC 58955

SAVCALC calculates the soil aggressiveness value (SAV) based on four soil characteristics: resistivity, pH, water content, and sulfide content.

AGEEST 59280

AGGEST estimates the time of external corrosion failure for tanks, vaulted pipes, and above-ground pipes.

SIZDIST 59815

SIZDIST creates the volume distribution for all of the releases from the model run. This may be used as output from the model.

RESTART

RESTART initializes all the detection options that are put into use in year zero for existing tanks.

FIX 61180

FIX reinitializes the variables associated with components that are replaced.

VAPZERO 63020

VAPZERO resets the variables associated with vapor wells when a component is replaced.

DETDIST 63175

DETDIST creates the time distribution for all of the releases from the model run. This may be used as output from the model.

COATS 63345

COATS determines the time of failure for coatings.

SECCON 63805

SECCON calculates the date of failure for various secondary containment devices.

LKPIPE 64005

LKPIPE uses the Rossum model to determine if a leak has developed in a pipe.

INTREPL 64330

INTREPL resamples the probability of interior localized corrosion for a component that has been replaced.

EXTREPL 64715

EXTREPL resamples the exterior corosion rate for the component that has been replaced.

VOLADJ 65075

VOLADJ adjusts the release volumes for treatment processes so that they reflect the amount of hazardous constituent that has been released.

RETRO 65390

RETRO initializes the variables used to turn on the containment when partial secondary or cathodic protection are put into use in year zero for existing tanks.

```
00010 PROGRAM TREE(INPUT,OUTPUT,FILINPT,RESB1,TRTM,RELB1=265/265,EXEC=
00015+250/250,SKIPS,FREQ,TAPE8=RELB1,TAPE9=500,TAPE10=RESB1,TAPE11=
00020+FILINPT,TAPE12=EXEC,TAPE13=SKIPS,TAPE14=TRTM,TAPE15=FREQ)
00025 COMMON/RETR/RETROFT
00030 LOGICAL RETROFT
00035 COMMON/RET1/TLINE(3),TVLT(3),TCPAD(3),TAPAD(3),TCBRM(3),TABRM(3),
00040+TDIK(5),TCUR(5),TPASP(5),TPCOP(5),TPLIN(5),TCATTIM
00045 REAL TLINE,TVLT,TCPAD,TAPAD,TCBRM,TABRM,TDIK,TCUR,TPASP,TPCOP,
00050+TPLIN,TCATTIM
00055 COMMON/RET2/TVAULT,TLINER,TCONPAD,TASPPAD,TCBERM,TABERM,TDIKE,
00060+TCURB,TASPAD,TCOPAD,TPLINER,TNOSEC,TPIPSEC,TLVAULT,TULVALT,
00065+TCATST,TPICATH
00070 LOGICAL TVAULT,TLINER,TCONPAD,TASPPAD,TCBERM,TABERM,TDIKE,TCURB,
00075+TASPAD,TCOPAD,TPLINER,TNOSEC,TPIPSEC,TLVAULT,TULVALT,
00080+TCATST,TPICATH
00085 COMMON/OFL5/OPVLOE(2),OPVLON(2)
00090 REAL OPVLOE,OPVLON
00095 INTEGER YRADJ,TEMPFAL,FALTMP1(10),FALTMP3(10),FALTMP7(10)
00100 REAL TEMPVOL,CALCVOL,FALTIME,FALTMP2(10),
00105+      FALTMP5(10)
00110 COMMON/LEVOP/OPLEV
00115 REAL OPLEV
00120 COMMON/EFFIC/TRTEFF,DVOLFR
00125 REAL TRTEFF,DVOLFR
00130 COMMON/TKFRAC/TANKTIM(3)
00135 REAL TANKTIM
00140 COMMON/WINSP/WEEKINS
00145 LOGICAL WEEKINS
00150 COMMON/PI2TIM/DIKTIM(5),CURTIM(5),PASPTIM(5),PCOPTIM(5),PLINTIM(5)
00155 REAL DIKTIM,CURTIM,PASPTIM,PCOPTIM,PLINTIM
00160 COMMON/CONPERM/PERMREL(3)
00165 REAL PERMREL,PI,SAREA,CNPERM
00170 COMMON/NYR/NYEAR
00175 INTEGER NYEAR
00180 COMMON/MOINV/MINV,MINT
00185 REAL MINV
00190 INTEGER MINT
00195 COMMON/CONCTM/CONCTIM(3)
00200 REAL CONCTIM
00205 COMMON/CTFL/CTFLAG
00210 LOGICAL CTFLAG
00215 LOGICAL FAIL5,SKLKTKS,SKLKFAS,BASERUN
00220 INTEGER YREV(11),YREV1(11),YREVP(11),YREVP1(11),NEXTRUN
00225 INTEGER YREVW(11),YREVW1(11)
00230 REAL DBS
00235 COMMON/LKLEN/PILKWID(5),PILKLEN(5)
00240 REAL PILKWID,PILKLEN
00245 COMMON/CWID/PIDFWID(5),RPPIWID(5),TKDFWID(3),RPTKWID(3),WLDFWID
00250+(5),GKDFWID(5),RPWLWID(5)
00255 REAL PIDFWID,RPPIWID,TKDFWID,RPTKWID,WLDFWID,
00260+GKDFWID,RPWLWID
00265 COMMON/CLEN/PIDFLEN(5),RPPILEN(5),TKDFLEN(3),RPTKLEN(3),WLDFLEN
00270+(3),GKDFLEN(5),RPWLLEN(5)
00275 REAL PIDFLEN,RPPILEN,TKDFLEN,RPTKLEN,WLDFLEN,
00280+GKDFLEN,RPWLLEN
00285 COMMON/MOF/MOFILL(2)
00290 REAL MOFILL
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00295 COMMON/OPERAT/BATCH,CONT
00300       COMMON/AX/IY
00305 COMMON/RUPLEN/CLENGTH(5),CWIDTH(5),CDIAM(5)
00310 REAL CLENGTH,CWIDTH,CDIAM
00315 COMMON/PIPELK/INTLK(5),PIPAGE(5),NUMLK(5),PRAN(5)
00320 INTEGER INTLK,NUMLK,PIPAGE
00325 REAL PRAN
00330 COMMON/LENMIN/CLENMIN(5),CWIDMIN(5),CDIMMIN(5)
00335 REAL CLENMIN,CWIDMIN,CDIMMIN
00340 COMMON/MODE/CDIMMOD(5)
00345 REAL CDIMMOD
00350 COMMON/DEFSEC/SECDEF(2)
00355 REAL SECDEF
00360 COMMON/CRAD/CRADLE
00365 LOGICAL CRADLE
00370 COMMON/PIFRP/PFRP
00375 LOGICAL PFRP
00380 COMMON/FLORTHK/FLORTHK
00385 COMMON/SECMAIN/MAINT
00390 LOGICAL MAINT
00395 COMMON/BERM/CBERM,ABERM
00400 LOGICAL CBERM,ABERM
00405 COMMON/TIME/APADTIM(3),CPADTIM(3),VLTTIM(3),CBRMTIM(3),ABRMTIM(3)
00410 REAL APADTIM,CPADTIM,VLTTIM,CBRMTIM,ABRMTIM
00415 COMMON/RUPT2/YRPVON(2),YRVLON(2)
00420 COMMON/RUPT1/OPCOM(2),PRESREL(2)
00425 REAL YRPVON,YRVLON,OPCOM,PRESREL
00430 COMMON/OFL1/OFTRCOM(2),OFTROM(2)
00435 COMMON/OFL2/MOPMOE(2),MOPVON(2),MOVLOE(2),MOVLON(2)
00440 COMMON/OFL3/MOPMCE(2),MOPMCN(2),MOVLCE(2),MOVLCN(2)
00445 COMMON/OFL4/MOALARM(2),FLVCN2(2),LEVIN2(2),FLVCN1(2),OPCOMM(2)
00450 REAL OFTRCOM,OFTROM
00455 REAL MOPMOE,MOPVON,MOVLOE,MOVLON
00460 REAL MOPMCE,MOPMCN,MOVLCE,MOVLCN
00465 REAL MOALARM,FLVCN2,LEVIN2,FLVCN1,OPCOMM
00470 INTEGER NOIL
00475 COMMON/SUSPSOL/SUSSOL(5)
00480 REAL SUSSOL
00485 COMMON/PH/PH(5)
00490 REAL PH
00495 REAL FRACH2O
00500 INTEGER OPDYYR,DAYSTOR
00505 REAL NUMBAT
00510 COMMON/OPDAY/OPDYYR
00515 COMMON/BTCHIN/NUMBAT,DAYSTOR
00520 COMMON/TECH/NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
00525 COMMON/OPR1/AUTOMAT,MANUAL
00530 COMMON/SHUT/AUTSHUT
00535 LOGICAL MANUAL,AUTOMAT
00540 COMMON/OPCL/OPEN,CLOSED
00545 LOGICAL OPEN,CLOSED
00550 LOGICAL BATCH,CONT,PCSTEEL,
00555+PSSTEEL,IGWASTE,AUTSHUT,NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP
00560+,STORAGE,ACTCARB
00565 COMMON/PMATL/PCSTEEL,PSSTEEL
00570 COMMON/IYRNO/IYRNUM
00575 COMMON/LOOPCT/NPI,NTK
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00580 INTEGER NPI,NTK
00585 COMMON/FRAC/AGFRAC,PAGFRAC,AGCONFR,UGCONFR
00590 REAL AGFRAC,PAGFRAC,AGCONFR,UGCONFR
00595 COMMON/VLREM/TTREMVL,TPREMVL
00600 REAL TTREMVL,TPREMVL
00605 COMMON/TEMPS/TPIPMON,TTKTST,TTK1TST,TTK5TST,TTKSTST,
00610+ TPITST,TPI1TST,TPI5TST,TPISTST,TMNMETH(6),TULTRTS
00615+ ,TMINVL,TWINVL,TIINVL,EXMINV,EXWINV,EXIINV
00620 REAL TMINVL,TWINVL,TIINVL,EXMINV,EXWINV,EXIINV
00625 LOGICAL TPIPMON,TTKTST,TTK1TST,TTK5TST,TTKSTST,TPITST,
00630+ TPI1TST,TPI5TST,TPISTST,TMNMETH,TULTRTS,TANKREP
00635 COMMON/TANKREP/TANKREP
00640 COMMON/AGSTART/AGPOPUL,AGTKLK
00645 INTEGER AGPOPUL,AGTKLK,AGTKAGE,YRO,IYRNUM,J,OTNONLK
00650 INTEGER MM
00655 COMMON/TESTING/TNK1TST,TNK5TST,PIP1TST,PIP5TST
00660 COMMON/UNDET/TSUB,TSURF,SUBSURF,SURF
00665 REAL TSUB,TSURF,SUBSURF,SURF
00670 REAL TCLVOL,TTCVOL
00675 COMMON/CCLEAN/TCLVOL,TTCVOL
00680 INTEGER TANKAGE,COUNT1
00685 COMMON/TANKAGE/TANKAGE
00690 REAL TRVOL
00695 COMMON/RCLEAN/TRVOL
00700 CHARACTER LAB(166)*51,FNAME*64,TITLE*110
00705 CHARACTER TITLE1*110
00710 INTEGER FALNUM,FALNUM1,FALNUM3,FALNUM4,FALNUM7
00715 COMMON/FALNUM/FALNUM,FALNUM1(100),FALNUM2(100),FALNUM3(100),
00720+  FALNUM4(100),FALNUM5(100),FALNUM7(100)
00725 COMMON/FALNUM6/FALNUM6(100)
00730 CHARACTER FALNUM6*2
00735 REAL FALNUM2,FALNUM5
00740 REAL VOL1
00745 COMMON/LOWVOL1/VOL1
00750 COMMON/DISCH/DISCRT(5),DISCTIM(5),DISCFR(5),VEHTANK,THRUPUT
00755 REAL DISCRT,DISCTIM,DISCFR,VEHTANK,THRUPUT
00760 COMMON/INVCNTL/INVCNTL
00765 LOGICAL INVCNTL
00770 REAL PPNDPTH
00775 COMMON/CONTAM/PPNDPTH,TPNDPTH
00780*
00785 COMMON/MCGDROP/MCWHORT,GDROP
00790 REAL MCWHORT,GDROP
00795 LOGICAL TNK1TST,TNK5TST,PIP1TST,PIP5TST,TNKSTST,PIPSTST
00800 COMMON/SEMITST/TNKSTST,PIPSTST
00805 LOGICAL BAKFILL
00810 COMMON/BAKFILL/BAKFILL(4)
00815 COMMON/PIPETIM/PIPDEF(5),WLDDEF(5),GSKDEF(5),PIPLK(5),
00820+GSKLK(5),RUPPIP(5)
00825 COMMON/TANKTIM/TNKDEF(3),TNKLK(3),RUPTNK(3)
00830 COMMON/SURFTIM/LOOSE,HOSPORT,PMPLK(5),RUPWLD(5),VENT
00835 COMMON/SUFTIM/HOSPERM,DRANPMP(5)
00840
00845 INTEGER PIPDEF,WLDDEF,GSKDEF,PIPLK,GSKLK,RUPPIP
00850 INTEGER TNKDEF,TNKLK,RUPTNK
00855 INTEGER LOOSE,HOSPORT,PMPLK,RUPWLD,VENT
00860 INTEGER HOSPERM,DRANPMP
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00865 COMMON/RUPPROB/TNKRUP2(2),TNKRUP(2),WLDRUP(2),PIPRUP(2),PORTHOS(2)
00870 COMMON/RUPPR1/PERMHOS(2),PMPDRAN(2)
00875 REAL PERMHOS,PMPDRAN
00880 REAL TNKRUP,TNKRUP2,WLDRUP,PIPRUP,PORTHOS
00885 COMMON/SPLPRB/LOOSCON(2)
00890 REAL LOOSCON
00895 COMMON/FIDITYP/FILLING,DISCHRG
00900 INTEGER FILLING,DISCHRG
00905 COMMON/PUMPTYP/PORTFP,PORTDP
00910 LOGICAL PORTFP,PORTDP
00915 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
00920 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
00925 COMMON/ANC/ANCIL
00930 LOGICAL ANCIL
00935 COMMON/LIFCOR/LIFCOR(2,5)
00940 REAL LIFCOR,INCFACT
00945 COMMON/SOIL/SATSOIL,SPH,RESIS,SULFSOL
00950  REAL RESIS,SPH
00955 LOGICAL SATSOIL,SULFSOL
00960 COMMON/CORE/PCORE(5),GCORE(5),PMCORE(5),TCORE(3),TCORE2(3)
00965 COMMON/CORE1/PCORE2(5),PIEXT2(5),PIEXLO2(5)
00970 REAL PCORE2,PIEXT2,PIEXLO2
00975 REAL PCORE,GCORE,PMCORE,TCORE,TCORE2
00980 COMMON/CONT/UGCONT(3),AGCONT(3),PIPCONT(5),NUGCONT(3),NAGCONT(3)
00985+,NPICONT(5)
00990 INTEGER UGCONT,AGCONT,PIPCONT,NUGCONT,NAGCONT,NPICONT
00995 COMMON/PIPCON/DIKE,CURB,ASPAD,COPAD,PLINER
01000 LOGICAL DIKE,CURB,ASPAD,COPAD,PLINER
01005 COMMON/DEFPROB/LIFDEF(2,7),GSKINC(2)
01010 REAL LIFDEF,GSKINC
01015 COMMON/CONNECT/WELDFLG,GASKET
01020 LOGICAL WELDFLG,GASKET
01025 COMMON/TKCONT/CONCPAD,ASPHPAD
01030 COMMON/LINE/LINETIM(3)
01035 COMMON/WALL/TK2WALL,PI2WALL
01040 LOGICAL CONCPAD,ASPHPAD
01045 REAL LINETIM
01050 LOGICAL TK2WALL,PI2WALL
01055 COMMON/THICK/TANKI(3),TANK2I(3)
01060 COMMON/EXTHI/TANKE(3),TANK2E(3)
01065 REAL TANKI,TANK2I
01070 REAL TANKE,TANK2E
01075 COMMON/MATPAR/APAR,CPAR,APARPI,CPARPI,APARPM,CPARPM
01080 REAL APAR,CPAR,APARPI,CPARPI,APARPM,CPARPM
01085 REAL A(7),CC(7)
01090
01095 COMMON/STRESS/STRESS(5),CORTHDS(2)
01100 COMMON/THICKNS/PIPEI(5),PUMPI(5),GASKI(5)
01105 COMMON/EXTHICK/PIPEE(5),PUMPE(5),GASKE(5),PIPE2E(5),PIPE2I(5)
01110 COMMON/ITHICK/IPIPE(5),IPUMP(5),ITANK(3),IGASK(5),ITANK2(3)
01115 COMMON/DIAM/PDIAM(5)
01120 REAL IPIPE,IPUMP,ITANK,IGASK,ITANK2
01125 REAL PIPEI,PUMPI,GASKI,PDIAM
01130 REAL PIPEE,PUMPE,GASKE,PIPE2E,PIPE2I
01135 REAL STRESS,CORTHDS
01140 COMMON/VENT/VCORE,VENTI,VENTE,IVENT,VLOCAL,VNTLOC,VEXT,
01145+VEXTLOC
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01150 REAL VNTLOC
01155 REAL VCORE,VENTI,VENTE,IVENT,VLOCAL,VEXT,VEXTLOC
01160 COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
01165 LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
01170 COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
01175 LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
01180 COMMON/TKGEOM/HORIZ,VERT
01185 LOGICAL HORIZ,VERT
01190 COMMON/TANKDM/TLENGTH(3),TWIDTH(3),THEIGHT(3),UGTHGHT(3),
01195+AGTHGHT(3),DIAM(3),LENGTH(3)
01200 REAL TLENGTH,TWIDTH,THEIGHT,UGTHGHT,AGTHGHT,DIAM,LENGTH
01205 COMMON/COATS/COATING(4,3,5)
01210 LOGICAL COATING
01215 COMMON/COATIM/ICOATIM(3,5),ECOATIM(3,5)
01220 REAL ICOATIM,ECOATIM
01225 COMMON/CATHLOS/CATHLOS
01230 REAL CATHLOS
01235 COMMON/CATHOD/CATFAIL
01240 LOGICAL CATFAIL
01245 COMMON/TKINFO/FRACTUG,TNKCAP(3)
01250 REAL FRACTUG,TNKCAP
01255 REAL CATTIM,CATHINS,CATREP
01260 COMMON/CATSYS/CATTIM
01265 COMMON/CATMAIN/MAINTEN
01270 REAL MAINTEN
01275 INTEGER FAC
01280 REAL E(5)
01285 COMMON/FILL/FILLRT(5),FILLTIM(5),FILLFR(5),FILLVOL(5)
01290 REAL FILLRT,FILLTIM,FILLFR,FILLVOL
01295       COMMON/CATREL/ANUCAT(2,7),IGPROD
01300       REAL ANUCAT,IGPROD
01305 COMMON/CATAST/CATASTR(12)
01310 INTEGER CATASTR
01315 COMMON/CATAS/VANDAL,WIND,EARTHQU,FLOOD,FIREXPL,FIRE
01320 INTEGER VANDAL,WIND,EARTHQU,FLOOD,FIREXPL,FIRE
01325 COMMON/REGION/COASTAL,FLOODPL,EARTHZN
01330 LOGICAL COASTAL,FLOODPL,EARTHZN
01335 COMMON/OVER/MOLEVIN(2)
01340 REAL MOLEVIN
01345 COMMON/TIMCONV/HRSMO,MINMO,DAYMO
01350
01355 REAL HRSMO,MINMO,DAYMO
01360 COMMON/INVEN/MINVLIM,IINVLIM,WINVLIM
01365
01370 REAL MINVLIM,IINVLIM,WINVLIM
01375 COMMON/PRINSP/PIPINSF(2),TNKINSF(2),PMPINSF(2),SECINSP(2)
01380 REAL PIPINSF,TNKINSF,PMPINSF,SECINSP
01385 COMMON/TSTFLAG/TKTSTG,PITSTG,ULTRTST
01390 LOGICAL TKTSTG,PITSTG,ULTRTST
01395 COMMON/TPLIMIT/PITSLIM,TKTSLIM,PIMNLIM
01400 REAL PITSLIM,TKTSLIM,PIMNLIM
01405 COMMON/TSTMON/PITEST,TKTEST,ULTEST,LYSTEST
01410 INTEGER PITEST,TKTEST,ULTEST,LYSTEST
01415 REAL PMOPEN,TMOPEN
01420 COMMON/MONTHLY/PMOPEN,TMOPEN
01425 REAL LYSIM,LYSDPTH,PLYSIM,TPNDPTH
01430 COMMON/LYS/LYSIM(2),LYSDPTH,PLYSIM
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01435 COMMON/ALARM/INTERST(5,2),INTER,PIINTER(5,2),PINTER
01440 REAL INTERST,INTER,PIINTER,PINTER
01445 COMMON/INSP/INSPECT(4)
01450 LOGICAL INSPECT
01455 COMMON/WSTCON/SGRAV
01460 REAL SGRAV
01465 COMMON/PRESS/PRESS(5,5)
01470 REAL PRESS
01475 COMMON/MATL/TNKMATL,PIPMATL
01480 INTEGER TNKMATL,PIPMATL
01485 COMMON/OPHRS/OPHRSDY
01490 REAL OPHRSDY
01495 COMMON/SOILCH/SPHER,VOID,DPART
01500 REAL SPHER,VOID,DPART
01505 COMMON/CHARAC/DENS,VISCOS
01510 REAL DENS,VISCOS
01515 COMMON/COUNT/NPIPDEF(5),NWLDDEF(5),NGSKDEF(5),NPIPLK(5),NGSKLK(5),
01520+NRUPPIP(5),NPMPLK(5),NRUPWLD(5),NTNKLK(3),NTNKDEF(3),NRUPTNK(3)
01525 REAL NPIPDEF,NWLDDEF,NGSKDEF,NPIPLK,NGSKLK,NRUPPIP,NPMPLK,NRUPWLD,
01530+     NTNKLK,NTNKDEF,NRUPTNK
01535 COMMON/VOLTOT/TVOLUME
01540 REAL TVOLUME
01545 COMMON/CDIAM/PIDFDIA(5),PILKDIA(5),PMLKDIA(5),GKLKDIA(5),TKLKDIA
01550+(3)
01555 REAL PIDFDIA,PILKDIA,PMLKDIA,GKLKDIA,TKLKDIA
01560 COMMON/DAVOL1/LOSEVOL,OVERVOL(12),HOSEVOL,PMLKVOL(5),RPWLVOL(5)
01565 REAL LOSEVOL,OVERVOL,HOSEVOL,PMLKVOL,RPWLVOL
01570 COMMON/VOL2/ PIDEFVL(5),WLDEFVL(5),GKDEFVL(5),PILKVOL(5),GKLKVOL
01575+(5),RPPIVOL(5)
01580 REAL PIDEFVL,WLDEFVL,GKDEFVL,PILKVOL,GKLKVOL,RPPIVOL
01585 COMMON/VOL3/ TKDEFVL(3),TKLKVOL(3),RPTKVOL(3)
01590 REAL TKDEFVL,TKLKVOL,RPTKVOL
01595 COMMON/RATE1/ PIDEFRT(5),WLDEFRT(5),GKDEFRT(5),PILKRT(5),GKLKRT
01600+(5),RPPIRT(5)
01605 REAL PIDEFRT,WLDEFRT,GKDEFRT,PILKRT,GKLKRT,RPPIRT
01610 COMMON/RATE2/ TKDEFRT(3),TKLKRT(3),RPTKRT(3)
01615 COMMON/RATE3/ PMLKRT(5),RPWLRT(5)
01620 REAL TKDEFRT,TKLKRT,RPTKRT,PMLKRT,RPWLRT
01625 COMMON/LIN/LINER
01630 LOGICAL LINER
01635 COMMON/WATER/GWDPTH
01640 REAL GWDPTH
01645 REAL PIPLEN
01650 COMMON/PIPEDM/PIPLEN(5)
01655 COMMON/MONIT/MONMETH(7),PIPMON
01660 LOGICAL MONMETH,PIPMON
01665 COMMON/VOLCOMP/TCVOL
01670 REAL TCVOL
01675 LOGICAL CONVTPD,ASPVTPD
01680 COMMON/OTHSEC/CONVTPD,ASPVTPD
01685 COMMON/DEFFLAG/DLTNK(3),DDTNK(3),DRTNK(3),DLGSK(5),DDGSK(5),
01690+DDWLD(5),DRWLD(5),DLPIP(5),DRPIP(5),DDPIP(5),DLPMP(5),DALL
01695 LOGICAL DLTNK,DDTNK,DRTNK,DLGSK,DDGSK,DDWLD,DRWLD,DLPIP,DRPIP,
01700+DDPIP,DLPMP,DALL
01705 REAL VTIME
01710 COMMON/VTIME/VTIME(3)
01715 REAL VAPWDIS
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01720 COMMON/VAPWDIS/VAPWDIS(3)
01725 COMMON/MASSDIF/DIFFI,DIFF1,DIFF2,VAPRESS
01730 REAL DIFFI,DIFF1,DIFF2,VAPRESS
01735 COMMON/THRESH/LOWER,FLASHTM,FLASHX,FLASHVL,POOF,FLASHDP,FLASHPT
01740 REAL LOWER,FLASHTM,FLASHX,FLASHVL,POOF,FLASHDP,FLASHPT
01745 LOGICAL SOIL
01750 COMMON/SOILTYP/SOIL(4)
01755 INTEGER PTSTFRQ,TTSTFRQ,UTSTFRQ,LTSTFRQ
01760 COMMON/FREQ/PTSTFRQ,TTSTFRQ,UTSTFRQ,LTSTFRQ
01765 COMMON/GEOL/POSZ,THETA,NFFLAG,POR,THETAP,PERM
01770 REAL POSZ,THETA,POR,THETAP,PERM
01775 LOGICAL PIREPAR,TKREPAR,PMREPAR
01780 COMMON/PITRE/PIREPAR(5),TKREPAR(3),PMREPAR(5)
01785 INTEGER NFFLAG
01790 COMMON/BYPASS/WLDFLGR,WLDFLGD,GSKFLGL,GSKFLGD
01795 LOGICAL WLDFLGR,WLDFLGD,GSKFLGL,GSKFLGD
01800 INTEGER NONLEAK,AGGFAIL,AGNYFAL,AGCORNO,AGFLASH,AGTKREP,AGPLUME
01805 INTEGER AGPL15
01810 INTEGER AGUNDET,AGPIPNO
01815 REAL CUMREL,AGPLVOL,AGPLARE,AGUNSAT
01820+,AGTKIST
01825 COMMON/AGG/NONLEAK,AGGFAIL,AGNYFAL,AGCORNO,CUMREL,AGPIPNO,
01830+AGTKREP,AGPLUME,
01835+AGPLVOL,AGPLARE,AGUNSAT,AGPL15,AGUNDET
01840+,AGTKIST,AGFLASH
01845 COMMON/ISEED/ISEED
01850 INTEGER ISEED
01855 INTEGER SEED
01860 COMMON/INV/MONINV,WEEKINV
01865 LOGICAL MONINV,WEEKINV
01870 COMMON/DISTSIZ/NSIZE(14)
01875 INTEGER NSIZE
01880 COMMON/VAPPRB/VAPSENS,VSENSOR
01885 REAL VAPSENS,VSENSOR
01890 COMMON/VAPOR/TKDFVAP,TKRPVAP,TKLKVAP,PIDFVAP(5),PIRPVAP(5),
01895+ PILKVAP(5),WGDFVAP(5),WGLRVAP(5),PMPVAP(5)
01900 COMMON/VFLAG/VAPFLG,VAPDET
01905 REAL TKDFVAP,TKRPVAP,TKLKVAP,PIDFVAP,PIRPVAP,PILKVAP,
01910+     WGDFVAP,WGLRVAP,PMPVAP
01915 COMMON/SAV/SAV
01920 LOGICAL VAPFLG,VAPDET
01925 COMMON/LP/LPAR,LPARPI
01930 REAL LPAR,LPARPI,SAV
01935 COMMON/DC/DCFACT
01940 REAL DCFACT,DCPRB
01945 COMMON/SAVAGE/UGTLOW,UGTMED,UGTHIGH,AGTALL
01950 REAL UGTLOW,UGTMED,UGTHIGH,AGTALL
01955 REAL AGGAGE,AVGAGE
01960 COMMON/DTDIST/DETSIZE(12)
01965 INTEGER DETSIZE
01970 COMMON/FLSHPT/FLASHON,FLREMED
01975 LOGICAL FLASHON,FLREMED
01980 DIMENSION UGTLOW(7,2),UGTMED(7,2),UGTHIGH(7,2),AGTALL(7,2)
01985   DIMENSION POROS(4),RESID(4),RESIDP(6,4)
01990   DIMENSION U(5),X(5),Y(5)
01995 DIMENSION AGUNDET(40),AGTKIST(500)
02000 DIMENSION TVOLUME(40)
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02005 DIMENSION TCVOL(40)
02010 DIMENSION PTSTFRQ(40),TTSTFRQ(40),UTSTFRQ(5)
02015 DATA(CDIMMIN(I),I=1,5)/.0156,.0156,.0156,0.,.0156/
02020 DATA(CDIAM(I),I=1,5)/.25,.25,.25,0.,.25/
02025 DATA(CDIMMOD(I),I=1,5)/.03125,.03125,.03125,0.,.03125/
02030 DATA(CWIDMIN(I),I=1,5)/.1,0.,0.,0.,0./
02035 DATA(CLENMIN(I),I=1,5)/1.,0.,3.,0.,0./
02040 DATA DCPRB/0.10/
02045 DATA(UGTLOW(I,1),I=1,7)/0.0,0.0,0.0,.063,.240,.483,.699/
02050 DATA(UGTLOW(I,2),I=1,7)/0.,4.,9.,14.,19.,24.,30./
02055 DATA(UGTMED(I,1),I=1,7)/0.0,0.0,.111,.291,.540,.673,.766/
02060 DATA(UGTMED(I,2),I=1,7)/0.,4.,9.,14.,19.,24.,30./
02065 DATA(UGTHIGH(I,1),I=1,7)/0.0,0.0,.267,.499,.765,.799,.833/
02070 DATA(UGTHIGH(I,2),I=1,7)/0.,4.,9.,14.,19.,24.,30./
02075 DATA(AGTALL(I,1),I=1,7)/0.0,0.0,0.0,.0315,.120,.2415,.3445/
02080 DATA(AGTALL(I,2),I=1,7)/0.,4.,9.,14.,19.,24.,30./
02085 DATA(STRESS(I),I=1,5)/13700.,18700.,13700.,13700.,13700./
02090 DATA(CORTHDS(I),I=1,2)/.25,.125/
02095 DATA(PDIAM(L),L=1,5)/2.,4.,2.,2.,2./
02100 DATA(PIPEI(L),L=1,5)/.157,.237,.157,.157,.157/
02105 DATA(PIPEE(L),L=1,5)/.157,.237,.157,.157,.157/
02110 DATA(GASKI(L),L=1,5)/1.188,1.375,1.188,1.188,1.188/
02115 DATA(GASKE(L),L=1,5)/1.188,1.375,1.188,1.188,1.188/
02120 DATA(PUMPI(L),L=1,5)/.25,.25,.25,.25,.25/
02125 DATA(PUMPE(L),L=1,5)/.25,.25,.25,.25,.25/
02130 DATA VENTI/.157/
02135 DATA VENTE/.157/
02140 DATA CATHLOS/.002/
02145 DATA(A(I),I=1,7)/1.,1.,1.3,1.3,1.,4.,0./
02150 DATA(CC(I),I=1,7)/1.,1.,.5,.5,1.,1.,0./
02155 DATA(E(I),I=1,5)/1.,1.,2.,0.,0./
02160 DATA PLYSIM/.01/
02165      DATA(RESIDP(1,I),I=1,4)/.10,.10,.10,.10/
02170      DATA(RESIDP(2,I),I=1,4)/.10,.10,.10,.10/
02175      DATA(RESIDP(3,I),I=1,4)/.15,.15,.15,.15/
02180      DATA(RESIDP(4,I),I=1,4)/.20,.20,.20,.20/
02185      DATA(RESIDP(5,I),I=1,4)/.20,.20,.20,.20/
02190      DATA(RESIDP(6,I),I=1,4)/.10,.10,.10,.10/
02195 DATA PI/3.1416/
02200******************************************
02205 DO 66666 L=1,5
02210    SUSSOL(L)=0.
02215    PH(L)=7.
02220 66666 CONTINUE
02225 READ(11,'(A)') FNAME
02230 OPEN(9,FILE=FNAME,STATUS='OLD')
02235 701 FORMAT(A51,I6)
02240 612 FORMAT(I4)
02245 702 FORMAT(A51)
02250 7070 FORMAT(A110)
02255 703 FORMAT(A51,L7)
02260 704 FORMAT(A51,F19.10)
02265 705 FORMAT(A17,10(I2,1X))
02270 706 FORMAT(A51,F6.2)
02275 707 FORMAT(A51,F10.1)
02280 708 FORMAT(A51,F5.3)
02285 709 FORMAT(A51,F9.6)
```

```
02290 710 FORMAT(A51;F12.10)
02295 711 FORMAT(A17,5(I2,1X))
02300 713 FORMAT(/A51,F9.2)
02305 714 FORMAT(A51,3(F4.1,1X))
02310 715 FORMAT(4(A10))
02315 READ(9,7070) TITLE
02320 READ(9,7070) TITLE1
02325 READ(9,701) LAB(1),FAC
02330 READ(9,703) LAB(156),BASERUN
02335 READ(9,703) LAB(161),SKLKTKS
02340 READ(9,703) LAB(157),SKLKFAS
02345 READ(9,701)LAB(140),YRO
02350 READ(9,701) LAB(2),NYEAR
02355 READ(9,701) LAB(3),OPDYYR
02360 READ(9,706) LAB(4),OPHRSDY
02365 READ(9,703) LAB(148),EARTHZN
02370 READ(9,703) LAB(149),FLOODPL
02375 READ(9,703) LAB(150),COASTAL
02380 READ(9,703) LAB(91),NEUT
02385 READ(9,703) LAB(90),CHRED
02390 READ(9,703) LAB(82),CYNOX
02395 READ(9,703) LAB(49),PRECIP
02400 READ(9,703) LAB(48),DISTILL
02405 READ(9,703) LAB(47),EVAP
02410 READ(9,703) LAB(43),STORAGE
02415 READ(9,703) LAB(42),ACTCARB
02420 READ(9,708) LAB(5),NUMBAT
02425 READ(9,701) LAB(153),DAYSTOR
02430 READ(9,703) LAB(33),BATCH
02435 READ(9,703) LAB(34),CONT
02440 READ(9,703) LAB(35),MANUAL
02445 READ(9,703) LAB(36),AUTOMAT
02450 READ(9,703) LAB(37),OPEN
02455 READ(9,703) LAB(38),CLOSED
02460 READ(9,703) LAB(89),AUTSHUT
02465 READ(9,703) LAB(6),UGTANK
02470 READ(9,703) LAB(7),IGTANK
02475 READ(9,709) LAB(11),FRACTUG
02480 READ(9,703) LAB(8),AGTANK
02485 READ(9,703) LAB(10),CRADLE
02490 READ(9,704) LAB(146),UGCONFR
02495 READ(9,704) LAB(147),AGCONFR
02500 READ(9,703) LAB(12),TK2WALL
02505 READ(9,703) LAB(166),RETROFT
02510 READ(9,703) LAB(13),CONCPAD
02515 IF(CONCPAD)CBERM=.TRUE.
02520 READ(9,703) LAB(14),ASPHPAD
02525 IF(ASPHPAD)ABERM=.TRUE.
02530 READ(9,703) LAB(15),ULVAULT
02535 READ(9,703) LAB(16),LVAULT
02540 READ(9,703) LAB(17),LINER
02545 READ(9,703) LAB(18),CONVTPD
02550 READ(9,703) LAB(19),ASPVTPD
02555 READ(9,703) LAB(9),MAINT
02560 IF(CONCPAD.OR.ASPHPAD.OR.ULVAULT.OR.LVAULT.OR.LINER
02565+  .OR.CONVTPD.OR.ASPVTPD) THEN
02570   NOSECON=.FALSE.
```

```
ELSE
 NOSECON=.TRUE.
ENDIF
TCATST=.FALSE.
READ(9,703)  LAB(20),CSTEEL
READ(9,703)  LAB(21),SSTEEL
READ(9,703)  LAB(22),FRP
READ(9,703)  LAB(23),CATSTEL
READ(9,704)  LAB(116),CATHINS
READ(9,703)  LAB(24),CONCRT
READ(9,703)  LAB(39),PCSTEEL
READ(9,703)  LAB(40),PSSTEEL
READ(9,703)  LAB(41),PFRP
READ(9,707)  LAB(25),TNKCAP(1)
READ(9,707)  LAB(26),THRUPUT
READ(9,703)  LAB(27),HORIZ
READ(9,703)  LAB(28),VERT
READ(9,703)  LAB(29),COATING(1,3,1)
READ(9,703)  LAB(30),COATING(2,3,1)
READ(9,703)  LAB(31),COATING(3,3,1)
READ(9,703)  LAB(32),COATING(4,3,1)
DO 49084 L=2,NTK
COATING(1,3,L)=COATING(1,3,1)
COATING(2,3,L)=COATING(2,3,1)
COATING(3,3,L)=COATING(3,3,1)
COATING(4,3,L)=COATING(4,3,1)
49084 CONTINUE
READ(9,703)  LAB(133),COATING(1,1,1)
READ(9,703)  LAB(132),COATING(2,1,1)
READ(9,703)  LAB(126),COATING(3,1,1)
READ(9,703)  LAB(154),COATING(4,1,1)
DO 49083 L=2,NPI
COATING(1,1,L)=COATING(1,1,1)
COATING(2,1,L)=COATING(2,1,1)
COATING(3,1,L)=COATING(3,1,1)
COATING(4,1,L)=COATING(4,1,1)
49083 CONTINUE
COATING(1,2,1)=.FALSE.
COATING(2,2,1)=.FALSE.
COATING(3,2,1)=.FALSE.
COATING(4,2,1)=.TRUE.
DO 49085 L=2,NPI
COATING(1,2,L)=COATING(1,2,1)
COATING(2,2,L)=COATING(2,2,1)
COATING(3,2,L)=COATING(3,2,1)
COATING(4,2,L)=COATING(4,2,1)
49085 CONTINUE
READ(9,704)  LAB(44),DENS
READ(9,704)  LAB(45),SGRAV
READ(9,704)  LAB(46),VISCOS
READ(9,704)  LAB(115),FRACH2O
READ(9,704)  LAB(104),PH(1)
READ(9,704)  LAB(103),SUSSOL(1)
READ(9,704)  LAB(164),TRTEFF
READ(9,704)  LAB(165),DVOLFR
READ(9,703)  LAB(92),IGWASTE
READ(9,703)  LAB(50),UGPIPE
READ(9,703)  LAB(51),AGPIPE
READ(9,703)  LAB(117),PICATH
IF(CATSTEL)THEN
   PICATH=.FALSE.
  ELSEIF(PICATH)THEN
   CATSTEL=.TRUE.
  ELSE
ENDIF
READ(9,703)  LAB(52),WELDFLG
READ(9,703)  LAB(53),GASKET
READ(9,704)  LAB(54),PIPLEN(1)
READ(9,704)  LAB(62),PIPLEN(2)
READ(9,704)  LAB(63),PIPLEN(3)
READ(9,704)  LAB(80),PIPLEN(4)
READ(9,704)  LAB(81),PIPLEN(5)
READ(9,703)  LAB(160),PI2WALL
READ(9,703)  LAB(141),DIKE
READ(9,703)  LAB(142),CURB
READ(9,703)  LAB(143),ASPAD
READ(9,703)  LAB(144),COPAD
READ(9,703)  LAB(162),PLINER
READ(9,704)  LAB(145),PAGFRAC
READ(9,703)  LAB(55),AGPUMP
READ(9,702)  LAB(56)
READ(9,703)  LAB(57),INSPECT(4)
READ(9,703)  LAB(58),INSPECT(2)
READ(9,703)  LAB(163),WEEKINS
READ(9,703)  LAB(59),INSPECT(1)
READ(9,703)  LAB(60),INSPECT(3)
READ(9,703)  LAB(61),INVCNTL
READ(9,703),LAB(125),WEEKINV
READ(9,703),LAB(126),MONINV
READ(9,701),LAB(159),MINT
READ(9,704)  LAB(64),MINVLIM
MINV=MINVLIM
TMINVL=MINV
READ(9,704)  LAB(124),WINVLIM
READ(9,704)  LAB(122),IINVLIM
READ(9,704)  LAB(120),EXMINV
READ(9,704)  LAB(119),EXWINV
READ(9,704)  LAB(118),EXIINV
READ(9,703)  LAB(65),TKTSTG
READ(9,703)  LAB(130),TNKSTST
READ(9,703)  LAB(66),TNK1TST
READ(9,703)  LAB(67),TNK5TST
READ(9,705)  LAB(68),(TTSTFRQ(K),K=1,10)
READ(9,703)  LAB(69),PITSTG
READ(9,703)  LAB(131),PIPSTST
READ(9,703)  LAB(70),PIP1TST
READ(9,703)  LAB(71),PIP5TST
READ(9,705)  LAB(72),(PTSTFRQ(K),K=1,10)
READ(9,709)  LAB(152),TKTSLIM
READ(9,709)  LAB(136),PITSLIM
READ(9,709)  LAB(135),PIMNLIM
READ(9,703)  LAB(73),ULTRTST
READ(9,711)  LAB(74),(UTSTFRQ(K),K=1,5)
READ(9,703)  LAB(75),MONMETH(1)
```

```
03145 READ(9,703)  LAB(76),MONMETH(2)
03150 READ(9,703)  LAB(77),MONMETH(3)
03155 READ(9,703)  LAB(78),MONMETH(4)
03160 READ(9,703)  LAB(79),MONMETH(5)
03165 READ(9,703)  LAB(121),MONMETH(6)
03170 READ(9,703)  LAB(158),MONMETH(7)
03175 READ(9,703)  LAB(137),PIPMON
03180 READ(9,714)  LAB(83),(VAPWDIS(K),K=1,3)
03185 READ(9,704)  LAB(127),DIFFI
03190 READ(9,704)  LAB(128),VAPRESS
03195 READ(9,704)  LAB(129),LOWER
03200 READ(9,703) LAB(134),FLASHON
03205 READ(9,704)  LAB(138),FLASHPT
03210 READ(9,709) LAB(139),FLASHX
03215 READ(9,709) LAB(151),FLASHDP
03220 READ(9,704)  LAB(84),LYSDPTH
03225 READ(9,701)  LAB(85),LTSTFRQ
03230 READ(9,715)  LAB(86),LAB(87),LAB(88),LAB(155)
03235 READ(9,704)  LAB(93),RESIS
03240 READ(9,704)  LAB(94),SPH
03245 READ(9,703)  LAB(95),SULFSOL
03250 READ(9,702)  LAB(96)
03255 READ(9,703)  LAB(97),SATSOIL
03260 READ(9,702)  LAB(98)
03265 READ(9,702)  LAB(99)
03270 READ(9,702)  LAB(100)
03275 READ(9,702)  LAB(101)
03280 READ(9,702)  LAB(102)
03285 READ(9,704)  LAB(105),POSZ
03290 READ(9,703)  LAB(106),BAKFILL(1)
03295 READ(9,703)  LAB(107),BAKFILL(2)
03300 READ(9,703)  LAB(108),BAKFILL(3)
03305 READ(9,703)  LAB(109),BAKFILL(4)
03310 READ(9,703)  LAB(110),SOIL(1)
03315 READ(9,703)  LAB(111),SOIL(2)
03320 READ(9,703)  LAB(112),SOIL(3)
03325 READ(9,703)  LAB(113),SOIL(4)
03330 READ(9,704)  LAB(114),GWDPTH
03335 READ(9,701)  LAB(123),ISEED
03340 SEED=ISEED
03345***********************************
03350* THE OUTLET PIPE IS SIZED TO THE TO A 2 INCH DIAMETER PIPE
03355 IF((AGTANK.AND.(TNKCAP(1).GT.100000.)).OR.(.NOT.STORAGE))THEN
03360    PDIAM(2)=PDIAM(1)
03365    GASKI(2)=GASKI(1)
03370    GASKE(2)=GASKE(1)
03375    PIPEI(2)=PIPEI(1)
03380    PIPEE(2)=PIPEE(1)
03385 ENDIF
03390*************************
03395* MM IS USED IN THE SEEDING PROCESS TO THE RANDOM NUMBER GENERATOR
03400* SO THAT THE SAME FACILITY FOR EACH RUN WILL  START  WITH  THE  SAME
SEED
03405* FOR COMPARISON PURPOSES.
03410 MM=0
03415 DO 417 II=1,NYEAR
03420    MM=MM+II
```

```
03425 417 CONTINUE
03430* INITIALIZE TANK AND PIPE INTEGRITY TESTING FREQUENCIES.
03435 IF (TNK1TST) THEN
03440    DO 902 I=1,NYEAR
03445       TTSTFRQ(I)=0
03450    902 CONTINUE
03455    DO 745  I=1,NYEAR
03460       TTSTFRQ(I)=1
03465    745 CONTINUE
03470 ELSEIF (TNK5TST) THEN
03475 DO 663 I=1,NYEAR
03480   TTSTFRQ(I)=0
03485  663 CONTINUE
03490    DO 748 I=1,NYEAR
03495     TTSTFRQ(I)=5*I
03500     748 CONTINUE
03505 ELSE
03510  DO 636 I=11,NYEAR
03515     TTSTFRQ(I)=0
03520  636 CONTINUE
03525 ENDIF
03530 IF (PIP1TST) THEN
03535    DO 999 I=1,NYEAR
03540       PTSTFRQ(I)=0
03545    999 CONTINUE
03550    DO 766  I=1,NYEAR
03555       PTSTFRQ(I)=1
03560    766 CONTINUE
03565 ELSEIF (PIP5TST) THEN
03570 DO 655 I=1,NYEAR
03575   PTSTFRQ(I)=0
03580  655 CONTINUE
03585    DO 948 I=1,NYEAR
03590     PTSTFRQ(I)=5*I
03595     948 CONTINUE
03600 ELSE
03605  DO 637 I=11,NYEAR
03610    PTSTFRQ(I)=0
03615  637 CONTINUE
03620 ENDIF
03625* SET THE BACKFILL SOIL PARAMTETERS
03630 IF(BAKFILL(1)) THEN
03635 VOID=.95
03640 SPHER=.075
03645 DPART=6.6E-06
03650 ELSEIF(BAKFILL(2)) THEN
03655 VOID=.75
03660 SPHER=.34
03665 DPART=2.1E-04
03670 ELSEIF(BAKFILL(3)) THEN
03675 VOID=.53
03680 SPHER=.65
03685 DPART=8.2E-04
03690  ELSE
03695 VOID=.5
03700 SPHER=.7
03705 DPART=3.1E-02
```

```
03710 ENDIF
03715* OIL IS NOT BEING ANALYZED IN TANK FAILURE MODEL.  THE PERMEABILITY
03720* DOES NOT HAVE TO BE ADJUSTED.
03725 NOIL=0
03730 IF(NOIL.EQ.1) THEN
03735 NFFLAG=1
03740 ELSE
03745 NFFLAG=0
03750 ENDIF
03755* SET THE PARAMTERS DEPENDENT ON THE SOIL TYPE.
03760 IF  (SOIL(1)) THEN
03765    POR=0.5
03770    PERM=(1E-08)*(.12**NFFLAG)*.0102/(VISCOS/6.72E-02)
03775    THETA=.3
03780    NSTYPE=4
03785 ELSEIF (SOIL(2)) THEN
03790    POR=.35
03795    PERM=(1E-08)*(.02**NFFLAG)*.0102/(VISCOS/6.72E-02)
03800    THETA=.27
03805   NSTYPE=3
03810 ELSEIF(SOIL(3)) THEN
03815    POR=.35
03820    PERM=(1E-02)*(.6**NFFLAG)*.0102/(VISCOS/6.72E-02)
03825    THETA=.09
03830   NSTYPE=2
03835 ELSE
03840    POR=.25
03845    PERM=(1E-02)*(.4**NFFLAG)*.0102/(VISCOS/6.72E-02)
03850    THETA=.09
03855    NSTYPE=1
03860 ENDIF
03865 PERM=PERM*SGRAV
03870    IF(NFFLAG.EQ.1)THEN
03875       THETAP=RESIDP(NOIL,NSTYPE)
03880       ELSE
03885       THETAP=1.
03890       ENDIF
03895 HRSMO=720.
03900 MINMO=43200.
03905 DAYMO=30.
03910* PROBABILITY OF INSPECTION FAILURE OR DETECTION
03915 PIPINSF(1)=.1
03920 PMPINSF(1)=.1
03925 SECINSP(1)=.9
03930 TNKINSF(1)=.1
03935* PROBABILITY OF INTERSTITIAL MONITORING FAILURE
03940 INTER=0.1
03945    PINTER=0.1
03950 DO 19009 L=1,NPI
03955    PIINTER(L,1)=PINTER
03960    INTERST(L,1)=INTER
03965 19009 CONTINUE
03970* PROBABILITY OF VAPOR WELL SENSOR DETECTION/DEMAND
03975 VSENSOR=0.9
03980 VAPSENS=VSENSOR
03985* DISTRIBUTION PARAMETERS
03990* PARAMETERS VARY WITH MATERIAL TYPE AND WHETHER THERE IS COATING
```

```
* OR CATHODIC PROTECTION.
* TANK
 IF((UGTANK.OR.IGTANK).AND.(.NOT.VAULT))THEN
     IF(CSTEEL)THEN
         IF(COATING(4,3,1).AND.(.NOT.CATSTEL))THEN
*             NO COATING OR CATHODIC PROTECTION
             APAR=A(1)
             CPAR=CC(1)
             LPAR=1.0
           ELSEIF((.NOT.COATING(4,3,1)).AND.(.NOT.CATSTEL))THEN
*             COATED AND NO CATHODIC PROTECTION
             APAR=A(2)
             CPAR=CC(2)
             LPAR=1.0/0.77
             DO 310 I=1,6
                 UGTLOW(I,1)=UGTLOW(I,1)*LPAR
                 UGTMED(I,1)=UGTMED(I,1)*LPAR
                 UGTHIGH(I,1)=UGTHIGH(I,1)*LPAR
             310 CONTINUE
           ELSEIF(COATING(4,3,1).AND.CATSTEL)THEN
*             NO COATING AND IS CATHODICALLY PROTECTED
             APAR=A(5)
             CPAR=CC(5)
             LPAR=1.0
           ELSE
*             COATED AND CATHODICALLY PROTECTED
             APAR=A(5)
             CPAR=CC(5)
             LPAR=1.0/0.77
             DO 311 I=1,6
                 UGTLOW(I,1)=UGTLOW(I,1)*LPAR
                 UGTMED(I,1)=UGTMED(I,1)*LPAR
                 UGTHIGH(I,1)=UGTHIGH(I,1)*LPAR
             311 CONTINUE
       ENDIF
     ELSEIF(SSTEEL)THEN
       APAR=A(6)
       CPAR=CC(6)
           LPAR=1.0
     ELSE
*      FRP OR CONRETE
       APAR=A(7)
       CPAR=CC(7)
           LPAR=0.0
           DO 312 I=1,6
              UGTLOW(I,1)=UGTLOW(I,1)*LPAR
                UGTMED(I,1)=UGTMED(I,1)*LPAR
                UGTHIGH(I,1)=UGTHIGH(I,1)*LPAR
           312 CONTINUE
   ENDIF
 ELSE
*  AGTANK
   IF(CSTEEL)THEN
       IF(COATING(4,3,1).AND.(.NOT.CATSTEL))THEN
*          NO COATING OR CATHODIC PROTECTION
           APAR=A(3)
           CPAR=CC(3)
```

```
          LPAR=1.0
         ELSEIF((.NOT.COATING(4,3,1)).AND.(.NOT.CATSTEL))THEN
*         COATED AND NO CATHODIC PROTECTION
          APAR=A(4)
          CPAR=CC(4)
          LPAR=1.0/(0.5*0.77)
          DO 307 I=1,6
             UGTLOW(I,1)=UGTLOW(I,1)*LPAR
          307 CONTINUE
         ELSEIF(COATING(4,3,1).AND.CATSTEL)THEN
*         NO COATING AND IS CATHODICALLY PROTECTED
          APAR=A(4)
          CPAR=CC(4)
          LPAR=1.0
         ELSE
*         COATED AND CATHODICALLY PROTECTED
          APAR=A(4)
          CPAR=CC(4)
          LPAR=1.0/(0.5*.77)
          DO 308 I=1,6
             UGTLOW(I,1)=UGTLOW(I,1)*LPAR
          308 CONTINUE
       ENDIF
      ELSEIF(SSTEEL)THEN
       APAR=A(6)
       CPAR=CC(6)
          LPAR=1.0
      ELSE
*      FRP OR CONCRETE
       APAR=A(7)
       CPAR=CC(7)
          LPAR=0.0
          DO 539 I=1,6
             UGTLOW(I,1)=UGTLOW(I,1)*LPAR
          539 CONTINUE
    ENDIF
 ENDIF
* PIPE
 IF(UGPIPE)THEN
    IF(PCSTEEL)THEN
       IF(COATING(4,1,1).AND.(.NOT.CATSTEL))THEN
*         NO COATING OR CATHODIC PROTECTION
          APARPI=A(1)
          CPARPI=CC(1)
          LPARPI=1.0
         ELSEIF((.NOT.COATING(4,1,1)).AND.(.NOT.CATSTEL))THEN
*         COATED AND NO CATHODIC PROTECTION
          APARPI=A(2)
          CPARPI=CC(2)
          LPARPI=1.0/0.77
         ELSEIF(COATING(4,1,1).AND.CATSTEL)THEN
*         NO COATING AND IS CATHODICALLY PROTECTED
          APARPI=A(5)
          CPARPI=CC(5)
          LPARPI=1.0
         ELSE
*         COATED AND CATHODICALLY PROTECTED
```

```
         APARPI=A(5)
         CPARPI=CC(5)
         LPARPI=1.0/0.77
      ENDIF
     ELSEIF(PSSTEEL)THEN
      APARPI=A(6)
      CPARPI=CC(6)
         LPARPI=1.0
     ELSE
*     FRP OR CONCRETE
      APARPI=A(7)
      CPARPI=CC(7)
         LPARPI=0.0
   ENDIF
  ELSE
*  AGPIPE
   IF(PCSTEEL)THEN
      IF(COATING(4,1,1).AND.(.NOT.CATSTEL))THEN
*        NO COATING OR CATHODIC PROTECTION
         APARPI=A(3)
         CPARPI=CC(3)
         LPARPI=1.0
        ELSEIF((.NOT.COATING(4,1,1)).AND.(.NOT.CATSTEL))THEN
*        COATED AND NO CATHODIC PROTECTION
         APARPI=A(4)
         CPARPI=CC(4)
         LPARPI=1.0/(0.5*.77)
        ELSEIF(COATING(4,1,1).AND.CATSTEL)THEN
*        NO COATING AND IS CATHODICALLY PROTECTED
         APARPI=A(4)
         CPARPI=CC(4)
         LPARPI=1.0
        ELSE
*        COATED AND CATHODICALLY PROTECTED
         APARPI=A(4)
         CPARPI=CC(4)
         LPARPI=1.0/(.5*.77)
      ENDIF
     ELSEIF(PSSTEEL)THEN
      APARPI=A(6)
      CPARPI=CC(6)
         LPARPI=1.0
     ELSE
*     FRP OR CONCRETE
      APARPI=A(7)
      CPARPI=CC(7)
         LPARPI=0.0
   ENDIF
ENDIF
IF(AGPUMP)THEN
*  AGPUMP
   IF(CSTEEL)THEN
      IF(COATING(4,2,1).AND.(.NOT.CATSTEL))THEN
*        NO COATING OR CATHODIC PROTECTION
         APARPM=A(3)
         CPARPM=CC(3)
        ELSEIF((.NOT.COATING(4,2,1)).AND.(.NOT.CATSTEL))THEN
```

```
04850*         COATED AND NO CATHODIC PROTECTION
04855          APARPM=A(4)
04860          CPARPM=CC(4)
04865         ELSEIF(COATING(4,2,1).AND.CATSTEL)THEN
04870*         NO COATING AND IS CATHODICALLY PROTECTED
04875          APARPM=A(4)
04880          CPARPM=CC(4)
04885         ELSE
04890*         COATED AND CATHODICALLY PROTECTED
04895          APARPM=A(4)
04900          CPARPM=CC(4)
04905       ENDIF
04910      ELSEIF(SSTEEL)THEN
04915       APARPM=A(6)
04920       CPARPM=CC(6)
04925      ELSE
04930       APARPM=A(7)
04935       CPARPM=CC(7)
04940    ENDIF
04945   ELSE
04950   APARPM=0
04955   CPARPM=0
04960 ENDIF
04965* SET MATERIAL TYPE PARAMETERS
04970 PIPMATL=1
04975 IF(PSSTEEL)PIPMATL=2
04980 IF(PFRP)PIPMATL=3
04985 TNKMATL=1
04990 IF(SSTEEL)TNKMATL=2
04995 IF(FRP)TNKMATL=3
05000 IF(CONCRT)TNKMATL=4
05005*************************************************
05010* NTK:NUMBER OF TANKS IN THE PROCESS
05015* NPI:NUMBER OF PIPES IN THE PROCESS
05020 IF(STORAGE)THEN
05025 NTK=1
05030 NPI=2
05035 ENDIF
05040 IF(CYNOX.OR.CHRED.OR.PRECIP)THEN
05045    NTK=3
05050    NPI=5
05055 ENDIF
05060 IF(DISTILL)THEN
05065    NTK=2
05070    NPI=4
05075 ENDIF
05080*************************************************
05085* SOME PROBABILITIES ARE ADJUSTED BY A FACTOR DEPENDENT ON
05090* MATERIAL TYPE.
05095 TNKRUP(1)=5.3E-03*E(TNKMATL)
05100 TNKRUP2(1)=5.3E-03*E(TNKMATL)
05105 WLDRUP(1)=.005
05110 PIPRUP(1)=3.0E-03*E(PIPMATL)
05115 OPCOM(1)=3.0E-03
05120 PRESREL(1)=1.0E-05
05125* INSTALLATION DEFICEINCY PROBABILITIES
05130 LIFDEF(1,1)=0.
```

```
05135 LIFDEF(1,2)=0.
05140*QUALITY OF INSTALLATION INSPECTION
05145*NONE=0.0,LOW(VIS)=0.5,MED(VIS+WELD)=.75,HIGH(VIS+WELD+TIGHT)=.95
05150 LIFDEF(1,3)=.75
05155 IF(TKTSTG)LIFDEF(1,3)=.95
05160 LIFDEF(1,4)=0.
05165 LIFDEF(1,5)=.01
05170 LIFDEF(1,6)=0.
05175 LIFDEF(1,7)=0.
05180 SECDEF(1)=.03
05185* PROBILITY OF INTERIOR LOCALIZED CORROSION'
05190 LIFCOR(1,1)=.15*CPAR
05195 LIFCOR(1,5)=.04*CPARPI
05200*INITIALIZATIONS
05205*****************
05210 CATFAIL=.FALSE.
05215 DO 502 L=1,NPI
05220    PIREPAR(L)=.FALSE.
05225    DLGSK(L)=.FALSE.
05230    DDWLD(L)=.FALSE.
05235    DRWLD(L)=.FALSE.
05240    DDGSK(L)=.FALSE.
05245    DLPIP(L)=.FALSE.
05250    DDPIP(L)=.FALSE.
05255    DRPIP(L)=.FALSE.
05260     DLPMP(L)=.FALSE.
05265 PIPCONT(L)=0
05270 NPICONT(L)=0
05275    IF(L.LE.3)THEN
05280    TKREPAR(L)=.FALSE.
05285    DLTNK(L)=.FALSE.
05290    DDTNK(L)=.FALSE.
05295    DRTNK(L)=.FALSE.
05300    TCORE(L)=0.
05305    TCORE2(L)=0.
05310    ENDIF
05315    PCORE(L)=0.
05320    PMCORE(L)=0.
05325    GCORE(L)=0.
05330    PCORE2(L)=0.
05335    PIEXT2(L)=0.
05340    PIEXLO2(L)=0.
05345 502 CONTINUE
05350 DO 1077 IIII=1,14
05355     NSIZE(IIII)=0
05360 1077 CONTINUE
05365 DO 1177 IIII=1,12
05370    DETSIZE(IIII)=0
05375 1177 CONTINUE
05380 DALL=.FALSE.
05385 DO 1911 II=1,NYEAR
05390    AGUNDET(II)=0
05395 1911 CONTINUE
05400 DO 1912 II=1,FAC
05405    AGTK1ST(II)=0
05410 1912 CONTINUE
05415 HOSPORT=0
```

```
05420 LOOSE=0
05425 HOSPERM=0
05430 NONLEAK=0
05435 AGGFAIL=0
05440 AGNYFAL=0
05445 AGCORNO=0
05450 AGPIPNO=0
05455 AGFLASH=0
05460 CUMREL=0.
05465 AGPLUME=0
05470 AGPLVOL=0.
05475 AGPLARE=0.
05480 AGUNSAT=0.
05485 AGPL15=0
05490 AGTKREP=0
05495 FILLING=0
05500 DISCHRG=1
05505 PORTFP=.FALSE.
05510 PORTDP=.FALSE.
05515 VAULT=.FALSE.
05520 IF (LVAULT.OR.ULVAULT.OR.CONVTPD.OR.ASPVTPD) VAULT=.TRUE.
05525 PIPSEC=.FALSE.
05530 IF(DIKE.OR.CURB.OR.ASPAD.OR.COPAD.OR.PLINER) PIPSEC=.TRUE.
05535 IF(NOSECON) UGCONFR=0.
05540 IF(.NOT.PIPSEC) PAGFRAC=0.
05545 DO 47892 L=1,NPI
05550 DRANPMP(L)=0
05555     IF(.NOT.PIPSEC) PIPCONT(L)=1
05560     IF(L.LE.NTK) THEN
05565 UGCONT(L)=0
05570 AGCONT(L)=0
05575 IF(NOSECON)  THEN
05580       AGCONT(L)=1
05585        UGCONT(L)=1
05590  ENDIF
05595 NUGCONT(L)=0
05600 NAGCONT(L)=0
05605     ENDIF
05610 47892 CONTINUE
05615 DO 8532 KKK=1,3
05620 DO 832 III=1,5
05625 ICOATIM(KKK,III)=0.
05630 ECOATIM(KKK,III)=0.
05635 832 CONTINUE
05640 8532 CONTINUE
05645************************
05650* CATASTROPHIC FAILURE PROBABILITIES
05655 ANUCAT(1,2)=1E-06
05660 IF(COASTAL) THEN
05665     ANUCAT(1,3)=.014
05670   ELSE
05675     ANUCAT(1,3)=1.5E-04
05680 ENDIF
05685 IF(FLOODPL) THEN
05690*    FLOOD
05695     ANUCAT(1,5)=.005
05700   ELSE
```

```
05705     ANUCAT(1,5)=0.
05710 ENDIF
05715 IF(EARTHZN)THEN
05720     ANUCAT(1,4)=8E-04
05725   ELSE
05730     ANUCAT(1,4)=0.
05735 ENDIF
05740 IF(AGTANK.OR.IGTANK)THEN
05745     ANUCAT(1,7)=3E-03
05750   ELSE
05755     ANUCAT(1,7)=1E-03
05760 ENDIF
05765 ANUCAT(1,6)=1E-06
05770 IGPROD=1.
05775 CATREP=0
05780* OVERFLOW PROBABILITIES
05785 OFTRCOM(1)=.003
05790 OFTROM(1)=.027
05795 MOALARM(1)=.1
05800 LEVIN2(1)=.008
05805 FLVCN1(1)=9.4E-02
05810 IF(BATCH)THEN
05815     OPCOMM(1)=1-(1-.003)**(30.*NUMBAT)
05820 ELSE
05825  OPCOMM(1)=.086
05830 ENDIF
05835 CALL RANSET(ISEED)
05840* MAINTENANCE FACTOR RANGES BETWEEN 1 AND 3
05845 MAINTEN=FNU(1.,3.)
05850* SAVE INITIAL COMPONENT THICKNESSES
05855 DO 98 L=1,NPI
05860     IPIPE(L)=PIPEI(L)
05865     IPUMP(L)=PUMPI(L)
05870     IGASK(L)=GASKI(L)
05875 98 CONTINUE
05880* SIZE THE FIRST TANK AND SAVE INITIAL COMPONENT THICKNESSES
05885 L=1
05890 CALL TNKDIM(L)
05895 ITANK(L)=TANKI(L)
05900 ITANK2(L)=TANK2I(L)
05905 CALL SETCOST(L)
05910 IVENT=VENTI
05915* SET VAPOR TRANSPORT TIMES
05920 DO 81 I=1,3
05925     CALL SETVAP(I,VTIME(I),VAPWDIS(I),LOWER)
05930 81 CONTINUE
05935 CALL SETVAP(1,FLASHTM,FLASHX,FLASHPT)
05940 TTCVOL=0
05945 SAV=0.0
05950* SET OPERATING CHARACTERISTICS
05955 CALL SETOPAR
05960* MORE OVERFLOW PROBABILITIES
05965 FLVCN2(1)=.05
05970 IF(BATCH)THEN
05975 MOPMOE(1)=7.5E-05*FILLTIM(1)/60.
05980 MOPVON(1)=7.5E-07*FILLTIM(1)/60.
05985 MOVLOE(1)=3.4E-04*FILLTIM(1)/60.
```

```
05990 MOVLON(1)=3.4E-05*FILLTIM(1)/60.
05995 MOVLCE(1)=3.4E-04*FILLTIM(1)/60.
06000 MOVLCN(1)=3.4E-05*FILLTIM(1)/60.
06005 YRPVON(1)=8.0E-07*FILLTIM(1)/60.
06010 YRVLON(1)=8.2E-04*FILLTIM(1)/60.
06015 MOPMCE(1)=3.0E-04*FILLTIM(1)/60.
06020 MOPMCN(1)=3.0E-06*FILLTIM(1)/60.
06025 ELSE
06030 MOPMOE(1)=7.5E-05*FILLTIM(1)/(60.*2.)
06035 MOPVON(1)=7.5E-07*FILLTIM(1)/(60.*2.)
06040 MOVLOE(1)=3.4E-04*FILLTIM(1)/(60.*2.)
06045 MOVLON(1)=3.4E-05*FILLTIM(1)/(60.*2.)
06050 MOVLCE(1)=3.4E-04*FILLTIM(1)/(60.*2.)
06055 MOVLCN(1)=3.4E-05*FILLTIM(1)/(60.*2.)
06060 YRPVON(1)=8.0E-07*FILLTIM(1)/60.
06065 YRVLON(1)=8.2E-04*FILLTIM(1)/60.
06070 MOPMCE(1)=3.0E-04*FILLTIM(1)/(60.*2.)
06075 MOPMCN(1)=3.0E-06*FILLTIM(1)/(60.*2.)
06080 ENDIF
06085 IF(AUTOMAT)THEN
06090 OPVLOE(1)=1-(1-3.4E-04)**(OPHRSDY*OPDYYR/12.)
06095 OPVLON(1)=1-(1-3.4E-05)**(OPHRSDY*OPDYYR/12.)
06100 ELSE
06105 OPVLOE(1)=0.
06110 OPVLON(1)=0.
06115 ENDIF
06120* SIZE ANY OTHER TANKS AND SAVE THEIR INITIAL COMPONENT THICKNESSES
06125 IF(NTK.GT.1)THEN
06130 DO 80916 L=2,NTK
06135 IF(CHRED .OR.  CYNOX .OR.  PRECIP)THEN
06140    IF(L.EQ.2)THEN
06145       TNKCAP(L)=FILLRT(1)*2.*60/.8
06150    ELSEIF(L.EQ.3)THEN
06155       TNKCAP(L)=FILLRT(1)*4.*60./.8
06160    ENDIF
06165 ELSEIF(DISTILL)THEN
06170    IF(L.EQ.2)TNKCAP(L)=TNKCAP(1)
06175 ENDIF
06180 CALL TNKDIM(L)
06185 ITANK(L)=TANKI(L)
06190 ITANK2(L)=TANK2I(L)
06195 CALL SETCOST(L)
06200 80916 CONTINUE
06205 ENDIF
06210* SET APPROXIMATE OPERATING PRESSURES
06215 DO 77777 L=1,NTK
06220 IF(STORAGE)THEN
06225 PRESS(L,3)=THEIGHT(L)*0.5*DENS
06230 ELSE
06235 PRESS(L,3)=THEIGHT(L)*0.8*DENS
06240 ENDIF
06245 77777 CONTINUE
06250 IF(STORAGE)THEN
06255        IF(UGTANK) THEN
06260      PRESS(1,1)=DENS*8.0
06265      PRESS(2,1)=DENS*4.0
06270      PRESS(1,2)=620
```

```
   PRESS (2,2)=620
   PRESS (1,4)=DENS*10.0
   PRESS (1,5)=PRESS (1,4)
C  150/320   *(14.6)=6.84FT/S====0.73FT FRICTION LOSS
   PRESS (2,4)=0
   PRESS (2,5)=PRESS (2,4)
   ELSE
       PRESS (1,1)=(AGTHGHT (1)/2)*DENS+620
       IF (VERT.AND.(TNKCAP (1).GT.1000)) THEN
       PRESS (2,1)=(AGTHGHT (1)/2.)*DENS
       ELSE
        PRESS (2,1)=AGTHGHT (1)*DENS
       ENDIF
      IF (IGTANK) THEN
          IF (FRACTUG.LT..5) THEN
          PRESS (1,1)=(.5-FRACTUG)*THEIGHT (1)*DENS+620
             PRESS (2,1)=(.5-FRACTUG)*THEIGHT (1)*DENS
          ELSE
          PRESS (1,1)=620.
             PRESS (2,1)=1.
          ENDIF
         ENDIF
       PRESS (1,2)=PRESS (1,1)
       PRESS (2,2)=PRESS (1,2)
       PRESS (1,4)=PRESS (1,1)
       PRESS (2,4)=PRESS (2,1)
       PRESS (1,5)=PRESS (1,4)
       PRESS (2,5)=PRESS (2,4)
ENDIF
ENDIF
IF (CYNOX.OR.CHRED.OR.PRECIP) THEN
*  AGTANK OR IGTANK ONLY
       PRESS (1,1)=(AGTHGHT (1)*.8)*DENS+620
       PRESS (2,1)=(AGTHGHT (1)*.8)*DENS+620
       PRESS (3,1)=(AGTHGHT (2)*.8)*DENS+620
       PRESS (4,1)=620+(AGTHGHT (3)*.8)*DENS
       PRESS (5,1)=620+(AGTHGHT (3)*.8)*DENS
      IF (IGTANK) THEN
          IF (FRACTUG.LT..8) THEN
          PRESS (1,1)=(THEIGHT (1)*(.8-FRACTUG))*DENS+620
          PRESS (2,1)=(THEIGHT (1)*(.8-FRACTUG))*DENS+620
          PRESS (3,1)=(THEIGHT (2)*(.8-FRACTUG))*DENS+620
             PRESS (4,1)=620.+(THEIGHT (3)*(.8-FRACTUG))*DENS
             PRESS (5,1)=620.+(THEIGHT (3)*(.8-FRACTUG))*DENS
          ELSE
             PRESS (4,1)=620.
             PRESS (1,1)=620.
             PRESS (2,1)=620.
             PRESS (3,1)=620.
             PRESS (5,1)=620.
          ENDIF
         ENDIF
       PRESS (1,2)=PRESS (1,1)
       PRESS (2,2)=PRESS (2,1)
       PRESS (3,2)=PRESS (3,1)
       PRESS (4,2)=PRESS (4,1)
       PRESS (5,2)=PRESS (5,1)
```

```
  IF(AGTANK)THEN
      PRESS(1,4)=(AGTHGHT(1)*.8)*DENS+620.
      PRESS(2,4)=(AGTHGHT(1)*.8)*DENS
      PRESS(3,4)=(AGTHGHT(2)*.8)*DENS
      PRESS(4,4)=(AGTHGHT(3)*.8)*DENS
      PRESS(5,4)=(AGTHGHT(3)*.8)*DENS
  ELSE
   IF(FRACTUG.LT..8)THEN
      PRESS(1,4)=(THEIGHT(1)*(.8-FRACTUG))*DENS+620.
      PRESS(2,4)=(THEIGHT(1)*(.8-FRACTUG))*DENS
      PRESS(3,4)=(THEIGHT(2)*(.8-FRACTUG))*DENS
      PRESS(4,4)=(THEIGHT(3)*(.8-FRACTUG))*DENS
      PRESS(5,4)=(THEIGHT(3)*(.8-FRACTUG))*DENS
     ELSE
      PRESS(1,4)=620.
         PRESS(2,4)=1.
         PRESS(3,4)=1.
         PRESS(4,4)=1.
         PRESS(5,4)=1.
      ENDIF
  ENDIF
      PRESS(1,5)=PRESS(1,4)
      PRESS(2,5)=PRESS(2,4)
      PRESS(3,5)=PRESS(3,4)
      PRESS(4,5)=PRESS(4,4)
      PRESS(5,5)=PRESS(5,4)
ENDIF
IF(DISTILL)THEN
*  AGTANK OR IGTANK ONLY
      PRESS(1,1)=(AGTHGHT(1)*.8)*DENS+620
      PRESS(2,1)=DENS*3.0
      PRESS(3,1)=620+AGTHGHT(2)*.8*DENS
      PRESS(4,1)=620+AGTHGHT(1)*.8*DENS
     IF(IGTANK)THEN
         IF(FRACTUG.LT..8)THEN
            PRESS(1,1)=(THEIGHT(1)*(.8-FRACTUG))*DENS+620
            PRESS(3,1)=(THEIGHT(2)*(.8-FRACTUG))*DENS+620
            PRESS(4,1)=(THEIGHT(1)*(.8-FRACTUG))*DENS+620
         ELSE
            PRESS(1,1)=620.
            PRESS(3,1)=620.
            PRESS(4,1)=620.
         ENDIF
        ENDIF
      PRESS(1,2)=PRESS(1,1)
      PRESS(2,2)=PRESS(2,1)
      PRESS(3,2)=PRESS(3,1)
      PRESS(4,2)=PRESS(4,1)
  IF(AGTANK)THEN
      PRESS(1,4)=(AGTHGHT(1)*.8)*DENS+620
      PRESS(2,4)=PRESS(2,1)
      PRESS(3,4)=(AGTHGHT(2)*.8)*DENS
      PRESS(4,4)=(AGTHGHT(1)*.8)*DENS
  ELSE
   IF(FRACTUG.LT..8)THEN
      PRESS(1,4)=(THEIGHT(1)*(.8-FRACTUG))*DENS
      PRESS(2,4)=PRESS(2,1)
```

```
06845        PRESS(3,4)=(THEIGHT(2)*(.8-FRACTUG))*DENS
06850        PRESS(4,4)=(THEIGHT(1)*(.8-FRACTUG))*DENS
06855       ELSE
06860        PRESS(1,4)=620.
06865           PRESS(2,4)=PRESS(2,1)
06870           PRESS(3,4)=1.
06875           PRESS(4,4)=1.
06880        ENDIF
06885    ENDIF
06890        PRESS(1,5)=PRESS(1,4)
06895        PRESS(2,5)=PRESS(2,4)
06900        PRESS(3,5)=PRESS(3,4)
06905        PRESS(4,5)=PRESS(4,4)
06910 ENDIF
06915* CALCULATE THE SOIL AGGRESSIVENESS VALUE
06920 CALL SAVCALC(SAV)
06925* OUTPUT THE INPUTS
06930 WRITE(8,7080)TITLE
06935 WRITE(8,7080)TITLE1
06940 WRITE(15,7080)TITLE
06945 WRITE(15,7080)TITLE1
06950 WRITE(14,7080)TITLE
06955 WRITE(14,7080)TITLE1
06960 WRITE(10,7080)TITLE
06965 WRITE(10,7080)TITLE1
06970 WRITE(10,701)LAB(1),FAC
06975 IF(BASERUN)WRITE(10,702) LAB(156)
06980 IF(SKLKTKS)WRITE(10,702),LAB(161)
06985 IF(SKLKFAS)WRITE(10,702),LAB(157)
06990 WRITE(10,701)LAB(140),YRO
06995 WRITE(10,701)LAB(2),NYEAR
07000 WRITE(10,701) LAB(3),OPDYYR
07005 WRITE(10,706) LAB(4),OPHRSDY
07010 IF(EARTHZN)WRITE(10,702) LAB(148)
07015 IF(FLOODPL)WRITE(10,702) LAB(149)
07020 IF(COASTAL)WRITE(10,702) LAB(150)
07025 WRITE(10,703) LAB(91),NEUT
07030 WRITE(10,703) LAB(90),CHRED
07035 WRITE(10,703) LAB(82),CYNOX
07040 WRITE(10,703) LAB(49),PRECIP
07045 WRITE(10,703) LAB(48),DISTILL
07050 WRITE(10,703) LAB(47),EVAP
07055 WRITE(10,703) LAB(43),STORAGE
07060 WRITE(10,703) LAB(42),ACTCARB
07065 WRITE(10,708) LAB(5),NUMBAT
07070 WRITE(10,701) LAB(153),DAYSTOR
07075 WRITE(10,703) LAB(33),BATCH
07080 WRITE(10,703) LAB(34),CONT
07085 WRITE(10,703) LAB(35),MANUAL
07090 WRITE(10,703) LAB(36),AUTOMAT
07095 WRITE(10,703) LAB(37),OPEN
07100 WRITE(10,703) LAB(38),CLOSED
07105 WRITE(10,703) LAB(89),AUTSHUT
07110 IF  (UGTANK)WRITE(10,702),LAB(6)
07115 IF(IGTANK)WRITE(10,702),LAB(7)
07120 IF(IGTANK)WRITE(10,709),LAB(11),FRACTUG
07125 IF(AGTANK)WRITE(10,702),LAB(8)
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07130 IF(CRADLE)WRITE(10,702),LAB(10)
07135 WRITE(10,'(A)'),'***'
07140 WRITE(10,704) LAB(146),UGCONFR
07145 WRITE(10,704) LAB(147),AGCONFR
07150 IF(CONCPAD)WRITE(10,702),LAB(13)
07155 IF(ASPHPAD) WRITE(10,702),LAB(14)
07160 IF(ULVAULT) WRITE(10,702),LAB(15)
07165 IF(LVAULT) WRITE(10,702),LAB(16)
07170 IF (TK2WALL) WRITE(10,702),LAB(12)
07175 IF(RETROFT) WRITE(10,702),LAB(166)
07180 IF (LINER) WRITE(10,702),LAB(17)
07185 IF(ASPVTPD)WRITE(10,702),LAB(19)
07190 IF(CONVTPD)WRITE(10,702),LAB(18)
07195 IF(MAINT)WRITE(10,702)LAB(9)
07200 WRITE(10,'(A)'),'***'
07205 IF(CSTEEL)WRITE(10,702),LAB(20)
07210 IF(SSTEEL)WRITE(10,702),LAB(21)
07215 IF(FRP) WRITE(10,702),LAB(22)
07220 IF(CATSTEL.AND.(.NOT.PICATH))WRITE(10,702),LAB(23)
07225 WRITE(10,704) LAB(116),CATHINS
07230 IF(CONCRT)WRITE(10,702),LAB(24)
07235  WRITE(10,703) LAB(39),PCSTEEL
07240 WRITE (10,703) LAB(40),PSSTEEL
07245 WRITE (10,703) LAB(41),PFRP
07250 WRITE(10,707),LAB(25),TNKCAP(1)
07255 WRITE(10,707),LAB(26),THRUPUT
07260 IF(HORIZ)WRITE(10,702),LAB(27)
07265 IF(VERT) WRITE(10,702),LAB(28)
07270 IF(COATING(1,3,1))WRITE(10,702),LAB(29)
07275 IF(COATING(2,3,1))WRITE(10,702),LAB(30)
07280 IF(COATING(3,3,1))WRITE(10,702),LAB(31)
07285 IF(COATING(4,3,1)) WRITE(10,702),LAB(32)
07290 IF(COATING(1,1,1))WRITE(10,702),LAB(133)
07295 IF(COATING(2,1,1))WRITE(10,702),LAB(132)
07300 IF(COATING(3,1,1))WRITE(10,702),LAB(126)
07305 IF(COATING(4,1,1))WRITE(10,702),LAB(154)
07310 WRITE(10,'(A)'),'***'
07315 WRITE(10,702),LAB(33)
07320 WRITE(10,708),LAB(45),SGRAV
07325 WRITE(10,709),LAB(46),VISCOS
07330 WRITE(10,706),LAB(44),DENS
07335 WRITE(10,704) LAB(115),FRACH20
07340 WRITE(10,704) LAB(104),PH(1)
07345 WRITE(10,704) LAB(103),SUSSOL(1)
07350 WRITE(10,704) LAB(164),TRTEFF
07355 WRITE(10,704) LAB(165),DVOLFR
07360 WRITE(10,703) LAB(92),IGWASTE
07365 WRITE(10,'(A)'),'***'
07370 IF(PI2WALL)WRITE(10,702), LAB(160)
07375 IF(DIKE)WRITE(10,702),LAB(141)
07380 IF(CURB)WRITE(10,702),LAB(142)
07385 IF(ASPAD)WRITE(10,702),LAB(143)
07390 IF(COPAD)WRITE(10,702),LAB(144)
07395 IF(PLINER)WRITE(10,702),LAB(162)
07400 WRITE(10,704) LAB(145),PAGFRAC
07405 IF (AGPUMP) WRITE(10,702),LAB(55)
07410 IF (.NOT.AGPUMP) WRITE(10,702),LAB(56)
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07415 IF(AGPIPE)WRITE(10,702),LAB(51)
07420 IF(PICATH)WRITE(10,702),LAB(117)
07425 IF(UGPIPE)WRITE(10,702),LAB(50)
07430 IF(WELDFLG) WRITE(10,702),LAB(52)
07435 IF(GASKET) WRITE(10,702),LAB(53)
07440 WRITE(10,706),LAB(54),PIPLEN(1)
07445 WRITE(10,706),LAB(62),PIPLEN(2)
07450 WRITE(10,706),LAB(63),PIPLEN(3)
07455 WRITE(10,706),LAB(80),PIPLEN(4)
07460 WRITE(10,706),LAB(81),PIPLEN(5)
07465 WRITE(10,'(A)'),'***'
07470 IF(INSPECT(1))WRITE(10,702),LAB(59)
07475 IF(INSPECT(2))WRITE(10,702),LAB(58)
07480 IF(WEEKINS)WRITE(10,702),LAB(163)
07485 IF(INSPECT(3))WRITE(10,702),LAB(60)
07490 IF(INSPECT(4))WRITE(10,702),LAB(57)
07495 IF(INVCNTL) THEN
07500   WRITE(10,702),LAB(61)
07505 IF(WEEKINV)WRITE(10,702),LAB(125)
07510 IF(MONINV)WRITE(10,702),LAB(126)
07515 WRITE(10,701),LAB(159),MINT
07520   WRITE(10,708),LAB(64),MINVLIM
07525    WRITE(10,708),LAB(124),WINVLIM
07530   WRITE(10,708),LAB(122),IINVLIM
07535   WRITE(10,708),LAB(120),EXMINV
07540    WRITE(10,708),LAB(119),EXWINV
07545   WRITE(10,708),LAB(118),EXIINV
07550 ELSE
07555    WRITE(10,702),'NO '//LAB(61)
07560 ENDIF
07565 WRITE(10,'(A)'),'***'
07570 IF(TKTSTG) THEN
07575    WRITE(10,702),LAB(65)
07580    WRITE(10,709),LAB(152),TKTSLIM
07585    IF(TNKSTST)WRITE(10,702),LAB(130)
07590    IF(TNK1TST)WRITE(10,702),LAB(66)
07595    IF(TNK5TST)WRITE(10,702),LAB(67)
07600    IF(.NOT.(TNK1TST.OR.TNK5TST.OR.TNKSTST))WRITE(10,705),LAB(68),
07605+TTSTFRQ(1),TTSTFRQ(2),TTSTFRQ(3),TTSTFRQ(4),TTSTFRQ(5),TTSTFRQ(6),
07610+TTSTFRQ(7),TTSTFRQ(8),TTSTFRQ(9),TTSTFRQ(10)
07615 ENDIF
07620 IF(PITSTG) THEN
07625    WRITE(10,702),LAB(69)
07630    WRITE(10,709),LAB(136),PITSLIM
07635    IF(PIPSTST)WRITE(10,702),LAB(131)
07640    IF(PIP1TST)WRITE(10,702),LAB(70)
07645    IF(PIP5TST)WRITE(10,702),LAB(71)
07650    IF(.NOT.(PIP1TST.OR.PIP5TST.OR.TNKSTST))WRITE(10,705),LAB(72)
07655+,PTSTFRQ(1),PTSTFRQ(2),PTSTFRQ(3),PTSTFRQ(4),PTSTFRQ(5),PTSTFRQ
07660+(6),PTSTFRQ(7),PTSTFRQ(8),PTSTFRQ(9),PTSTFRQ(10)
07665 ENDIF
07670 IF (ULTRTST) THEN
07675     WRITE(10,702),LAB(73)
07680    WRITE(10,711),LAB(74),UTSTFRQ(1),UTSTFRQ(2),UTSTFRQ(3),
07685+UTSTFRQ(4),UTSTFRQ(5)
07690 ENDIF
07695 WRITE(10,'(A)'),'***'
```

```
IF(MONMETH(1))WRITE(10,702),LAB(75)
IF(MONMETH(2))WRITE(10,702),LAB(76)
IF(MONMETH(3))WRITE(10,702) LAB(77)
IF(MONMETH(6))WRITE(10,702) LAB(121)
IF(MONMETH(7))WRITE(10,702) LAB(158)
IF(PIPMON)THEN
   WRITE(10,702),LAB(137)
   WRITE(10,709),LAB(135),PIMNLIM
 ENDIF
IF (MONMETH(5)) THEN
WRITE(10,702),LAB(79)
WRITE(10,714),LAB(83),VAPWDIS(1),VAPWDIS(2),VAPWDIS(3)
WRITE(10,710) LAB(127),DIFFI
WRITE(10,710) LAB(128),VAPRESS
WRITE(10,710) LAB(129),LOWER
ENDIF
WRITE(10,702)LAB(134)
WRITE(10,710)LAB(138),FLASHPT
WRITE(10,709)LAB(139),FLASHX
WRITE(10,709)LAB(151),FLASHDP
IF (MONMETH(4)) THEN
    WRITE(10,702),LAB(78)
    WRITE(10,702),LAB(85)
    IF (LTSTFRQ.EQ.1)WRITE(10,702),LAB(86)
    IF (LTSTFRQ.EQ.2)WRITE(10,702),LAB(87)
    IF (LTSTFRQ.EQ.3)WRITE(10,702),LAB(88)
    IF (LTSTFRQ.EQ.4)WRITE(10,702),LAB(155)
    WRITE(10,706),LAB(84),LYSDPTH
ENDIF
WRITE(10,'(A)'),'***'
WRITE(10,'(A)'),'***'
IF (SOIL(1))WRITE(10,702),LAB(110)
IF (SOIL(2))WRITE(10,702),LAB(111)
IF (SOIL(3))WRITE(10,702),LAB(112)
IF (SOIL(4))WRITE(10,702),LAB(113)
IF (BAKFILL(1)) WRITE(10,702),LAB(106)
IF (BAKFILL(2)) WRITE(10,702),LAB(107)
IF (BAKFILL(3)) WRITE(10,702),LAB(108)
IF (BAKFILL(4)) WRITE(10,702),LAB(109)
WRITE(10,708),LAB(99),POR
WRITE(10,709),LAB(101),DPART
WRITE(10,708),LAB(100),VOID
WRITE(10,706),LAB(105),POSZ
WRITE(10,706),LAB(114),GWDPTH
IF(SATSOIL)WRITE(10,702),LAB(97)
IF(.NOT.SATSOIL)WRITE(10,702),LAB(98)
IF(SULFSOL) WRITE(10,702),LAB(95)
IF(.NOT.SULFSOL)WRITE(10,702),LAB(96)
WRITE(10,707),LAB(93),RESIS
WRITE(10,707),LAB(94),SPH
WRITE(10,708),LAB(102),SPHER
WRITE(10,706),'SOIL AGGRESSIVENESS VALUE                ',SAV
WRITE(10,'(A)'),'***'
WRITE(10,701) LAB(123),ISEED
WRITE(10,'(A)'),'***'
* INITIALIZE MORE PROBABILITIES
PERMHOS(1)=0
```

```
07985 IF(AGPUMP)THEN
07990 PMPDRAN(1)=1E-02
07995 ELSE
08000 PMPDRAN(1)=0.
08005 ENDIF
08010* BE CAREFUL WITH TANK SIZE AND PORTABLE HOSES
08015 IF(BATCH.AND.STORAGE.AND.(TNKCAP(1).LT.100000))THEN
08020 PORTHOS(1)=5E-03*DISCTIM(2)*DISCFR(2)*365./60.
08025 LOOSCON(1)=1E-02*DISCFR(2)*365.
08030 ELSE
08035 PORTHOS(1)=0.
08040 LOOSCON(1)=0.
08045 ENDIF
08050 MOLEVIN(1)=.15
08055 IF(STORAGE)THEN
08060    MOFILL(1)=.079
08065 ELSE
08070    MOFILL(1)=1.0
08075 ENDIF
08080*INITIALIZE MORE VARIABLES
08085 DO 563 J=1,NYEAR
08090    TVOLUME(J)=0.
08095      TCVOL(J)=0
08100 563 CONTINUE
08105 TVOL1=0
08110 IF(YRO.NE.0)THEN
08115   TMINVL=MINVLIM
08120   TWINVL=WINVLIM
08125   TIINVL=IINVLIM
08130   TPIPMON=PIPMON
08135   TULTRTS=ULTRTST
08140   TTKTST=TKTSTG
08145   TTK1TST=TNK1TST
08150   TTK5TST=TNK5TST
08155   TTKSTST=TNKSTST
08160   TPITST=PITSTG
08165   TPI1TST=PIP1TST
08170   TPI5TST=PIP5TST
08175   TPISTST=PIPSTST
08180   DO 69 II=1,6
08185     TMNMETH(II)=MONMETH(II)
08190   69 CONTINUE
08195 ENDIF
08200 AGTKAGE=0
08205 AGPOPUL=0
08210 AGTKLK=0
08215 COUNT1=0
08220 TTREMVL=0.
08225 TPREMVL=0.
08230 SEED=SEED+FAC
08235 IF(.NOT.BASERUN)READ(13,612) NEXTRUN
08240 IF(STORAGE)TNKCAP(2)=TNKCAP(1)
08245* NORMAL TANK OPERATING LEVELS
08250 IF(STORAGE)THEN
08255    OPLEV=0.5
08260 ELSE
08265    OPLEV=0.8
```

```
08270 ENDIF
08275* CALCULATE RELEASES DUE TO THE PERMEABILITY OF CONCRETE TANKS
08280 DO 21234 L=1,NTK
08285     IF (CONCRT) THEN
08290         IF (VERT) THEN
08295      SAREA=PI*(TWIDTH(L)/2.)**2.+PI*TWIDTH(L)*THEIGHT(L)*.5*OPLEV
08300         ELSE
08305  SAREA=TWIDTH(L)*TLENGTH(L)+(2.*OPLEV)*(TWIDTH(L)*TLENGTH(L)+
08310+            TWIDTH(L)*TWIDTH(L))
08315         ENDIF
08320         CNPERM=2.5E-09
08325     PERMREL(L)=(1+(PRESS(L,3)/DENS)/(ITANK(L)/12.))*CNPERM*SAREA*
08330+        646696.*(.0102/(VISCOS/6.72E-02))*(DENS/62.4)
08335     ELSE
08340         PERMREL(L)=0.
08345     ENDIF
08350 21234 CONTINUE
08355* ITERATION LOOP
08360 DO 100 I=1,FAC
08365 ISEED=SEED
08370*  SEED THE RANDOM NUMBER GENERATOR
08375 CALL RANSET(ISEED)
08380 IF (.NOT.BASERUN) THEN
08385     IF (I.EQ.NEXTRUN) THEN
08390        READ(13,612) NEXTRUN
08395     ELSE
08400        GO TO 62
08405     ENDIF
08410 ENDIF
08415* REINITIALIZE VARIABLES
08420 DO 45642 L=1,NYEAR
08425     TVOLUME(L)=0.
08430 45642 CONTINUE
08435 DO 87654 L=1,NPI
08440      INTLK(L)=0
08445      PIPAGE(L)=0
08450      PRAN(L)=FNU(0.,2.)
08455      NUMLK(L)=0
08460    PIPCONT(L)=0
08465 NPICONT(L)=0
08470 IF (L.LE.NTK) THEN
08475    AGCONT(L)=0
08480    NAGCONT(L)=0
08485    UGCONT(L)=0
08490    NUGCONT(L)=0
08495* SAMPLE TIME TO FAILURE
08500 IF (LINER) LINETIM(L)=FNN(35.,10.)
08505 IF (LVAULT) LINETIM(L)=FNN(9.,3.)
08510 IF (VAULT) CALL SECCON(5,FLORTHK,MAINT,VLTTIM(L))
08515 IF (CONCPAD) CALL SECCON(3,FLORTHK,MAINT,CPADTIM(L))
08520 IF (ASPHPAD) CALL SECCON(1,FLORTHK,MAINT,APADTIM(L))
08525 IF (CBERM) CALL SECCON(4,1.,MAINT,CBRMTIM(L))
08530 IF (ABERM) CALL SECCON(2,1.,MAINT,ABRMTIM(L))
08535 ENDIF
08540 IF (DIKE)  CALL SECCON(2,1.,MAINT,DIKTIM(L))
08545 IF (CURB)  CALL SECCON(4,1.,MAINT,CURTIM(L))
08550 IF (ASPAD)  CALL SECCON(1,.667,MAINT,PASPTIM(L))
```

```
08555 IF(COPAD) CALL SECCON(3.,.667,MAINT,PCOPTIM(L))
08560 IF(PLINER) PLINTIM(L)=FNN(35.,10.)
08565 IF(PLINER.AND.(ASPAD.OR.COPAD))PLINTIM(L)=FNN(9.,3.)
08570 IF(RETROFT)THEN
08575* ADD ON THE BENCHMARK YEAR FOR THOSE COMPONENTS THAT ARE RETROFITTED
08580  IF(L.LE.NTK)THEN
08585    TLINE(L)=LINETIM(L)+YRO
08590    LINETIM(L)=100
08595    TVLT(L)=VLTTIM(L)+YRO
08600    VLTTIM(L)=100
08605    TCPAD(L)=CPADTIM(L)+YRO
08610    CPADTIM(L)=100
08615    TAPAD(L)=APADTIM(L)+YRO
08620    APADTIM(L)=100
08625    TCBRM(L)=CBRMTIM(L)+YRO
08630    CBRMTIM(L)=100
08635    TABRM(L)=ABRMTIM(L)+YRO
08640    ABRMTIM(L)=100
08645    AGCONT(L)=1
08650    UGCONT(L)=1
08655  ENDIF
08660  TDIK(L)=DIKTIM(L)+YRO
08665  DIKTIM(L)=100
08670  PIPCONT(L)=1
08675  TCUR(L)=CURTIM(L)+YRO
08680  CURTIM(L)=100
08685  TPASP(L)=PASPTIM(L)+YRO
08690  PASPTIM(L)=100
08695  TPCOP(L)=PCOPTIM(L)+YRO
08700  PCOPTIM(L)=100
08705  TPLIN(L)=PLINTIM(L)+YRO
08710  PLINTIM(L)=100
08715 ENDIF
08720 87654 CONTINUE
08725 IF(RETROFT)THEN
08730* STORE THE FLAGS THAT WILL BE TURNED ON WHEN THE RETROFIT OCCURS
08735    TCATST=CATSTEL
08740    TPICATH=PICATH
08745    TVAULT=VAULT
08750    TULVALT=ULVAULT
08755    TNOSEC=NOSECON
08760    TPIPSEC=PIPSEC
08765    TLVAULT=LVAULT
08770    TLINER=LINER
08775    TCONPAD=CONCPAD
08780    TASPPAD=ASPHPAD
08785    TCBERM=CBERM
08790    TABERM=ABERM
08795    TDIKE=DIKE
08800    TCURB=CURB
08805    TASPAD=ASPAD
08810    TCOPAD=COPAD
08815    TPLINER=PLINER
08820    NOSECON=.TRUE.
08825    PIPSEC=.FALSE.
08830    VAULT=.FALSE.
08835     ULVAULT=.FALSE.
```

```
   LVAULT=.FALSE.
   LINER=.FALSE.
   CONCPAD=.FALSE.
   ASPHPAD=.FALSE.
   CBERM=.FALSE.
   ABERM=.FALSE.
   DIKE=.FALSE.
   CURB=.FALSE.
   ASPAD=.FALSE.
   COPAD=.FALSE.
   PLINER=.FALSE.
   CATSTEL=.FALSE.
   PICATH=.FALSE.
ENDIF
* INITIALIZATIONS
POOF=FLASHTM
    TSUB=0
       TSURF=0
     SUBSURF=0
      SURF=0
   FLREMED=.FALSE.
CTFLAG=.FALSE.
TANKREP=.FALSE.
DO 970 II=1,100
 FALNUM1(II)=0
    FALNUM2(II)=0
    FALNUM5(II)=0
    FALNUM6(II)='ND'
  FALNUM3(II)=0
  FALNUM4(II)=0
  FALNUM7(II)=0
970 CONTINUE
FALNUM=0
* MCWHORTER-NELSON ESTIMATE FOR THE MONTHLY PENETRATION DEPTH OF THE
* CONSTITUENT INTO THE SOIL
MCWHORT=PERM*.01*(1/(POR-THETA))*2.592E06/.3048
TCLVOL=0
TRVOL=0
TMOPEN=0
TPNDPTH=0
PPNDPTH=0
GDROP=0
DO 901 L=1,NPI
  GKDEFRT(L)=0
   PIDEFVL(L)=0
   RPPIVOL(L)=0
   WLDEFVL(L)=0
   GKDEFVL(L)=0
   RPWLVOL(L)=0
   PILKVOL(L)=0
   GKLKVOL(L)=0
   PMLKVOL(L)=0
   PIDEFRT(L)=0
   RPPIRT(L)=0
   WLDEFRT(L)=0
   RPWLRT(L)=0
   PILKRT(L)=0
```

```
09125     GKLKRT(L)=0
09130     PMLKRT(L)=0
09135     RUPWLD(L)=0
09140     RUPPIP(L)=0
09145     PIPDEF(L)=0
09150     WLDDEF(L)=0
09155     GSKDEF(L)=0
09160 PIPLK(L)=0
09165 GSKLK(L)=0
09170 PMPLK(L)=0
09175 901 CONTINUE
09180 DO 79010 L=1,NTK
09185* SAMPLE THE FAILURE TIME FOR A CONCRETE TANK
09190 IF(CONCRT)CONCTIM(L)=FNN(35.,10.)
09195 TNKLK(L)=0
09200 RUPTNK(L)=0
09205 TNKDEF(L)=0
09210 TKDEFRT(L)=0
09215 RPTKRT(L)=0
09220 TKLKRT(L)=0
09225 TKDEFVL(L)=0
09230 RPTKVOL(L)=0
09235 TKLKVOL(L)=0
09240 79010 CONTINUE
09245 VENT=0
09250 TKDFVAP=0.
09255 TKRPVAP=0.
09260 TKLKVAP=0.
09265 DO 309 L=1,NPI
09270     NPIPDEF(L)=0
09275     NWLDDEF(L)=0
09280     NGSKDEF(L)=0
09285     NPIPLK(L)=0
09290     NGSKLK(L)=0
09295     NRUPPIP(L)=0
09300     NPMPLK(L)=0
09305     NRUPWLD(L)=0
09310     WGLRVAP(L)=0.
09315     WGDFVAP(L)=0.
09320     PILKVAP(L)=0.
09325     PIDFVAP(L)=0.
09330       PIRPVAP(L)=0.
09335     PMPVAP(L)=0.
09340 NPICONT(L)=0
09345 309 CONTINUE
09350 DO 8309 L=1,NTK
09355 NAGCONT(L)=0
09360 NUGCONT(L)=0
09365 NTNKLK(L)=0
09370 NTNKDEF(L)=0
09375 NRUPTNK(L)=0
09380 8309 CONTINUE
09385* SAMPLE THE PROBABILITY OF DIRECT CURRENTS
09390 DCFLAG=FNB(DCPRB)
09395 IF(DCFLAG.EQ.1.)THEN
09400     DCFACT=FNBE(2.,1.,4.)
09405   ELSE
```

```
09410    DCFACT=1.0
09415 ENDIF
09420 IYRNUM=0
09425*SAMPLE THE FAILURE TIME OF THE COATING
09430 CALL COATS(1,1)
09435 CALL COATS(1,2)
09440 CALL COATS(3,1)
09445 CALL COATS(2,1)
09450 CALL COATS(2,2)
09455 MAINTEN=FNU(1.,3.)
09460* SAMPLE THE FAILURE TIME OF THE CATHODIC PROTECTION SYSTEM.  FAILURE
09465* TIME IS A FUNCTION OF THE QUALITY OF MAINTENANCE FOR THE SYSTEM.
09470 IF(CATSTEL.OR.TCATST)THEN
09475 IF(COATING(2,3,1).OR.COATING(3,3,1))THEN
09480 CATTIM=FNN(10.,5.)*MAINTEN+(ECOATIM(3,1)*FNB(.5))
09485 ELSE
09490 CATTIM=FNN(10.,5.)*MAINTEN
09495 ENDIF
09500*IF  THE  CATHODIC PROTECTION SYSTEM IS RETROFITTED, SAVE THE FAILURE
TIME.
09505 IF(RETROFT)THEN
09510    TCATTIM=CATTIM+YRO
09515    CATTIM=100.
09520 ENDIF
09525 ENDIF
09530* REINITIALIZE COMPONENT THICKNESSES AND PROBABILITIES
09535* FOR THE NEW ITERATION.
09540 DO 99 L=1,NPI
09545    PIPEI(L)=IPIPE(L)
09550    PIPEE(L)=IPIPE(L)
09555    PIPE2E(L)=IPIPE(L)
09560    PIPE2I(L)=IPIPE(L)
09565    PUMPI(L)=IPUMP(L)
09570    PUMPE(L)=IPUMP(L)
09575    GASKI(L)=IGASK(L)
09580    GASKE(L)=IGASK(L)
09585    PIINTER(L,1)=PINTER
09590 99 CONTINUE
09595 LYSIM(1)=PLYSIM
09600 VAPSENS=VSENSOR
09605 DO 9090 L=1,NTK
09610 INTERST(L,1)=INTER
09615 TANKI(L)=ITANK(L)
09620 TANKE(L)=ITANK(L)
09625 TANK2I(L)=ITANK2(L)
09630 TANK2E(L)=ITANK2(L)
09635 9090 CONTINUE
09640 VENTI=IVENT
09645 VENTE=IVENT
09650* REINITIALIZE FLAGS
09655    CATFAIL=.FALSE.
09660     WLDFLGR=.FALSE.
09665     GSKFLGL=.FALSE.
09670     WLDFLGD=.FALSE.
09675     GSKFLGD=.FALSE.
09680    VAPFLG=.FALSE.
09685* CALCULATE CORROSION/EROSION RATES
```

```
09690     CALL CORPRB
09695     CALL CORERAT
09700 IF(YRO.NE.0)THEN
09705   MINV=TMINVL
09710   WINVLIM=TWINVL
09715   IINVLIM=TIINVL
09720   ULTRTST=.FALSE.
09725   TKTSTG=.FALSE.
09730   TNK1TST=.FALSE.
09735   TNK5TST=.FALSE.
09740   TNKSTST=.FALSE.
09745   PITSTG=.FALSE.
09750   PIP1TST=.FALSE.
09755   PIP5TST=.FALSE.
09760   PIPSTST=.FALSE.
09765   MONMETH(1)=.TRUE.
09770   DO 68 II=2,6
09775     MONMETH(II)=.FALSE.
09780   68 CONTINUE
09785   PIPMON=.FALSE.
09790 ENDIF
09795* CALCULATE THE INTERIOR LOCALIZED CORROSION RATE
09800 CALL INTCORR
09805* YEAR LOOP
09810   DO 110 IYRNUM=1,NYEAR
09815* SEED THE RANDOM NUMBER CHAMBER
09820     ISEED=ISEED+IYRNUM
09825     CALL RANSET(ISEED)
09830     J=IYRNUM
09835* IF THE BENCHMARK YEAR HAS BEEN REACHED START ANY
09840* RETROFIT OPTIONS OR DETECTION OPTIONS.
09845  IF((IYRNUM.EQ.YRO).AND.RETROFT)CALL RETRO
09850     IF(YRO.NE.0.AND.IYRNUM.GE.YRO)J=IYRNUM-YRO+1
09855     IF(CATTIM.LE.IYRNUM)CATFAIL=.TRUE.
09860* REINITIALIZE WHEN THE BENCHMARK YEAR HAS BEEN REACHED
09865 IF(IYRNUM.EQ.YRO)THEN
09870     DO 77553 L=1,NPI
09875       IF(L.LE.NTK)THEN
09880         AGCONT(L)=0
09885         UGCONT(L)=1
09890         NAGCONT(L)=0
09895         NUGCONT(L)=0
09900         ENDIF
09905         PIPCONT(L)=0
09910         NPICONT(L)=0
09915     77553 CONTINUE
09920 ENDIF
09925 IF(IYRNUM.EQ.1)THEN
09930   TANKAGE=0
09935 ENDIF
09940 TANKAGE=TANKAGE+1
09945* SAMPLE FAULT TREES
09950     CALL CATREL
09955     CALL ANCILOS(J)
09960     CALL SPILLS
09965 DO 33445 L=1,NTK
09970     CALL TNKCONT(L)
```

```
33445 CONTINUE
*  TANK LOSSES
   ANCIL=.FALSE.
   CALL LEAKRUP(ANCIL,J)
* ESTIMATE RELEASE VOLUMES
     CALL RELEASE(I,J,YRO)
* IF A TANK HAS FAILED BEFORE THE BENCHMARK YEAR HAS BEEN
* RELEASED, EXCLUDE IT FROM THE TANK POPULATION.
 IF(YRO.NE.0.AND.IYRNUM.LT.YRO.AND.TANKREP) GO TO 62
 IF(YRO.NE.0.AND.IYRNUM.LT.YRO.AND.FALNUM.NE.0.AND.(SKLKTKS.OR.
+        SKLKFAS))THEN
          DO 630 II=1,FALNUM
 IF(INT(MOD(FALNUM1(II),1000)/10).EQ.3.OR.INT(MOD(FALNUM1(II),1000)
+         /10).EQ.6)GO TO 62
 IF(IYRNUM.EQ.(YRO-1).AND.FALNUM6(II).EQ.'ND'.AND.SKLKFAS)GO TO 62
      630 CONTINUE
 ENDIF
 IF(CATSTEL.AND.CATFAIL)THEN
* SAMPLE IF THE CATHODIC PROTECTION SYSTEM FAILURE HAS
* BEEN DETECTED.  REPAIR THE SYSTEM IF IT IS DETECTED.
 CATREP=FNB(CATHINS)
 IF(CATREP.EQ.1)THEN
   CALL REPLAC(9,1)
   CATREP=0
 ENDIF
* ORGANIZE THE RESULTS USED TO GENERATE THE
* FREQUENCY TABLES.
 ENDIF
 IF(IYRNUM.GE.YRO)THEN
 IF(IYRNUM.EQ.NYEAR)THEN
     IF(BASERUN)WRITE(13,612) I
 IF(AGTANK)DBS=0.
 IF(IGTANK)DBS=UGTHGHT(1)/2.
 IF(UGTANK) DBS=(UGTHGHT(1)/2.)+PIPLEN(2)
 IF(VAULT.AND.UGTANK) DBS=UGTHGHT(1)+PIPLEN(2)
 IF(VAULT.AND.IGTANK) DBS=UGTHGHT(1)
 DO 617 II=1,11
     YREV(II)=0
     YREV1(II)=0
     YREVP(II)=0
     YREVP1(II)=0
     YREVW(II)=0
     YREVW1(II)=0
 617 CONTINUE
 ITKPNTR=1
 IPIPNTR=1
 DO 616 II=1,FALNUM
     IF(YREV(6).GT.0.)ITKPNTR=2
     IF(YREV(7).GT.0)ITKPNTR=3
     IF(YREV(8).GT.0)ITKPNTR=0
     IF(YREVP(6).GT.0.)IPIPNTR=2
     IF(YREVP(7).GT.0)IPIPNTR=3
     IF(YREVP(8).GT.0)IPIPNTR=0
     FAIL5=.FALSE.
     IF(YREV(1).EQ.0.AND.INT(MOD(FALNUM1(II),1000)/10.).EQ.6)THEN
        YREV(1)=INT((FALNUM7(II)-1)/12.+1)
            IF(YREV(1).EQ.0)YREV(1)=1
```

```
10260            FAIL5=.TRUE.
10265      ENDIF
10270      IF (YREV (2) .EQ.0.AND.INT (FALNUM1 (11) /1000) .EQ.3
10275+     .AND.INT (MOD (FALNUM1 (11) , 1000) /10) .EQ.3) THEN
10280            YREV (2) =INT ( (FALNUM7 (11) -1) /12.+1)
10285            IF (YREV (2) .EQ.0) YREV (2) =1
10290            FAIL5=.TRUE.
10295      ENDIF
10300  IF (YREV1 (2) .EQ.0.AND. (.NOT.FAIL5) .AND.INT (FALNUM1 (11) /1000) .EQ.3
10305+     .AND.INT (MOD (FALNUM1 (11) , 1000) /10) .EQ.3) THEN
10310            YREV1 (2) =INT ( (FALNUM7 (11) -1) /12.+1)
10315            IF (YREV1 (2) .EQ.0) YREV1 (2) =1
10320            FAIL5=.TRUE.
10325      ENDIF
10330      IF (YREVP (2) .EQ.0.AND.INT (FALNUM1 (11) /1000) .EQ.3.AND.
10335+     INT (MOD (FALNUM1 (11) , 1000) /10) .EQ.1) THEN
10340            YREVP (2) =INT ( (FALNUM7 (11) -1) /12.+1)
10345            IF (YREVP (2) .EQ.0) YREVP (2) =1
10350            FAIL5=.TRUE.
10355      ENDIF
10360  IF (YREVP1 (2) .EQ.0.AND. (.NOT.FAIL5) .AND.INT (FALNUM1 (11) /1000) .EQ.3
10365+     .AND.INT (MOD (FALNUM1 (11) , 1000) /10) .EQ.1) THEN
10370            YREVP1 (2) =INT ( (FALNUM7 (11) -1) /12.+1)
10375            IF (YREVP1 (2) .EQ.0) YREVP1 (2) =1
10380            FAIL5=.TRUE.
10385      ENDIF
10390      IF (YREV (3) .EQ.0.AND.INT (FALNUM1 (11) /1000.) .EQ.2.AND.
10395+        INT (MOD (FALNUM1 (11) , 1000) /10) .EQ.3) THEN
10400        YREV (3) =INT ( (FALNUM7 (11) -1) /12.+1)
10405            IF (YREV (3) .EQ.0) YREV (3) =1
10410        FAIL5=.TRUE.
10415      ENDIF
10420  IF (YREV1 (3) .EQ.0.AND. (.NOT.FAIL5) .AND.INT (FALNUM1 (11) /1000.) .EQ.2
10425+        .AND.INT (MOD (FALNUM1 (11) , 1000) /10) .EQ.3) THEN
10430        YREV1 (3) =INT ( (FALNUM7 (11) -1) /12.+1)
10435            IF (YREV1 (3) .EQ.0) YREV1 (3) =1
10440        FAIL5=.TRUE.
10445      ENDIF
10450      IF (YREVP (3) .EQ.0.AND.INT (FALNUM1 (11) /1000.) .EQ.2.AND.
10455+        INT (MOD (FALNUM1 (11) , 1000) /10) .EQ.1) THEN
10460        YREVP (3) =INT ( (FALNUM7 (11) -1) /12.+1)
10465            IF (YREVP (3) .EQ.0) YREVP (3) =1
10470        FAIL5=.TRUE.
10475      ENDIF
10480  IF (YREVP1 (3) .EQ.0.AND. (.NOT.FAIL5) .AND.INT (FALNUM1 (11) /1000.) .EQ.2
10485+        .AND.INT (MOD (FALNUM1 (11) , 1000) /10) .EQ.1) THEN
10490        YREVP1 (3) =INT ( (FALNUM7 (11) -1) /12.+1)
10495            IF (YREVP1 (3) .EQ.0) YREVP1 (3) =1
10500        FAIL5=.TRUE.
10505      ENDIF
10510      IF (YREVW (3) .EQ.0.AND. (INT (FALNUM1 (11) /1000.) .EQ.2.OR.
10515+      INT (FALNUM1 (11) /1000.) .EQ.3) .AND.
10520+       (INT (MOD (FALNUM1 (11) , 1000) /10) .EQ.4.OR.
10525+      INT (MOD (FALNUM1 (11) , 1000) /10) .EQ.5)) THEN
10530        YREVW (3) =INT ( (FALNUM7 (11) -1) /12.+1)
10535            IF (YREVW (3) .EQ.0) YREVW (3) =1
10540        FAIL5=.TRUE.
```

```
   ENDIF
IF(YREVW1(3).EQ.0.AND.(.NOT.FAIL5).AND.(INT(FALNUM1(11)/1000.)
    .EQ.2.OR.INT(FALNUM1(11)/1000.).EQ.3).AND.
     (INT(MOD(FALNUM1(11),1000)/10).EQ.4.OR.
    INT(MOD(FALNUM1(11),1000)/10).EQ.5))THEN
      YREVW1(3)=INT((FALNUM7(11)-1)/12.+1)
         IF(YREVW1(3).EQ.0)YREVW1(3)=1
      FAIL5=.TRUE.
   ENDIF
   IF(YREV(9).EQ.0.AND.INT(FALNUM1(11)/1000.).EQ.1.AND.
      INT(MOD(FALNUM1(11),1000)/10).EQ.3)THEN
      YREV(9)=INT((FALNUM7(11)-1)/12.+1)
         IF(YREV(9).EQ.0)YREV(9)=1
      FAIL5=.TRUE.
   ENDIF
   IF(YREVP(9).EQ.0.AND.INT(FALNUM1(11)/1000.).EQ.1.AND.
      INT(MOD(FALNUM1(11),1000)/10).EQ.1)THEN
      YREVP(9)=INT((FALNUM7(11)-1)/12.+1)
         IF(YREVP(9).EQ.0)YREVP(9)=1
      FAIL5=.TRUE.
   ENDIF
   IF(YREVW(9).EQ.0.AND.INT(FALNUM1(11)/1000.).EQ.1
     .AND.(INT(MOD(FALNUM1(11),1000)/10).EQ.4.OR.
    INT(MOD(FALNUM1(11),1000)/10).EQ.5))THEN
      YREVW(9)=INT((FALNUM7(11)-1)/12.+1)
         IF(YREVW(9).EQ.0)YREVW(9)=1
      FAIL5=.TRUE.
   ENDIF
   IF(YREV(4).EQ.0.AND.INT(MOD(FALNUM1(11),1000)/10.).EQ.8)
      THEN
      YREV(4)=INT((FALNUM7(11)-1)/12.+1)
         IF(YREV(4).EQ.0)YREV(4)=1
      FAIL5=.TRUE.
   ENDIF
IF(YREV1(4).EQ.0.AND.(.NOT.FAIL5).AND.INT(MOD(FALNUM1(11),1000)/
      10.).EQ.8)THEN
      YREV1(4)=INT((FALNUM7(11)-1)/12.+1)
         IF(YREV1(4).EQ.0)YREV1(4)=1
      FAIL5=.TRUE.
   ENDIF
   IF(YREV(10).EQ.0.AND.INT(MOD(FALNUM1(11),1000)/10.).EQ.7)
      THEN
      YREV(10)=INT((FALNUM7(11)-1)/12.+1)
         IF(YREV(10).EQ.0)YREV(10)=1
      FAIL5=.TRUE.
   ENDIF
IF(YREV1(10).EQ.0.AND.(.NOT.FAIL5).AND.INT(MOD(FALNUM1(11),1000)/
      10.).EQ.7)THEN
      YREV1(10)=INT((FALNUM7(11)-1)/12.+1)
         IF(YREV1(10).EQ.0)YREV1(10)=1
      FAIL5=.TRUE.
   ENDIF
   IF(YREV(11).EQ.0.AND.INT(MOD(FALNUM1(11),1000)/10.).EQ.9)
      THEN
      YREV(11)=INT((FALNUM7(11)-1)/12.+1)
         IF(YREV(11).EQ.0)YREV(11)=1
      FAIL5=.TRUE.
    ENDIF
IF (YREV1 (11) .EQ.0.AND. (.NOT.FAIL5) .AND. INT (MOD (FALNUM1 (11) , 1000) /
+       10.) .EQ. 10) THEN
        YREV1 (11) = INT ( (FALNUM7 (11) - 1) / 12.+1)
            IF (YREV1 (11) .EQ.0) YREV1 (11) = 1
        FAIL5=.TRUE.
    ENDIF
IF (YREV (5) .EQ.0.AND..NOT.FAIL5) YREV (5) = INT ( (FALNUM7 (11) - 1) / 12.+1)
    IF (YREV (6) .EQ.0.AND. ITKPNTR.EQ.1.AND. ( (INT (MOD (FALNUM1 (11) ,
+   1000) /10.) .EQ.3.AND.FALNUM6 (11) .NE. 'CA') .OR. INT (MOD
+(FALNUM1 (11) , 1000) /10.) .EQ.6) .AND. (FALNUM6 (11) .NE. 'ND') ) THEN
        YREV (6) = INT ( (FALNUM3 (11) - 1) / 12.+1)
            IF (YREV (6) .EQ.0) YREV (6) = 1
    ELSEIF (YREV (7) .EQ.0.AND. ITKPNTR.EQ.2.AND.
+( (INT (MOD (FALNUM1 (11) , 1000) /10.) .EQ.3.AND.FALNUM6 (11) .NE. 'CA')
+   .OR. INT (MOD (FALNUM1 (11) , 1000) /10.) .EQ.6.) .AND.
+   (FALNUM6 (11) .NE. 'ND') ) THEN
        YREV (7) = INT ( (FALNUM3 (11) - 1) / 12.+1)
            IF (YREV (7) .EQ.0) YREV (7) = 1
    ELSEIF (YREV (8) .EQ.0.AND. ITKPNTR.EQ.3.AND. ( (INT (MOD
+  (FALNUM1 (11) , 1000) / 10.) .EQ.3.AND.FALNUM6 (11) .NE. 'CA')
+ .OR. INT (MOD (FALNUM1 (11) , 1000) /10.) .EQ.6) .AND. (FALNUM6 (11) .NE.
+'ND') ) THEN
        YREV (8) = INT ( (FALNUM3 (11) - 1) / 12.+1)
            IF (YREV (8) .EQ.0) YREV (8) = 1
    ENDIF
    IF (YREVP (6) .EQ.0.AND. IPIPNTR.EQ.1.AND. ( (INT (MOD (FALNUM1 (11) ,
+   1000) /10.) .EQ.1.AND.FALNUM6 (11) .NE. 'CA') .OR. INT (
+   MOD (FALNUM1 (11) , 1000) /10.) .EQ.6) .AND. (FALNUM6 (11)
+   .NE. 'ND') ) THEN
        YREVP (6) = INT ( (FALNUM3 (11) - 1) / 12.+1)
            IF (YREVP (6) .EQ.0) YREVP (6) = 1
    ELSEIF (YREVP (7) .EQ.0.AND. IPIPNTR.EQ.2.AND.
+( (INT (MOD (FALNUM1 (11) , 1000) /10.) .EQ.1.AND.FALNUM6 (11) .NE. 'CA')
+   .OR. INT (MOD (FALNUM1 (11) , 1000) /10.) .EQ.6.) .AND. (FALNUM6 (11)
+   .NE. 'ND') ) THEN
        YREVP (7) = INT ( (FALNUM3 (11) - 1) / 12.+1)
            IF (YREVP (7) .EQ.0) YREVP (7) = 1
    ELSEIF (YREVP (8) .EQ.0.AND. IPIPNTR.EQ.3.AND. ( (INT (MOD
+  (FALNUM1 (11) , 1000) /10.) .EQ.1.AND.FALNUM6 (11) .NE. 'CA')
+ .OR. INT (MOD (FALNUM1 (11) , 1000) /10.) .EQ.6) .AND. (FALNUM6 (11)
+   .NE. 'ND') ) THEN
        YREVP (8) = INT ( (FALNUM3 (11) - 1) / 12.+1)
            IF (YREVP (8) .EQ.0) YREVP (8) = 1
    ENDIF
616 CONTINUE
615 FORMAT(11(1X,E10.3))
614 FORMAT(I3,1X,F6.3,1X,F5.3,9(1X,E10.3))
IF(.NOT.STORAGE)THEN
*  FOR TREATMENT TANKS THE AMOUNT OF UNTREATED WASTE
* THAT IS RELEASED MUST BE ESTIMATED FROM THE RELEASE
* VOLUME PROFILE.
    YRADJ=YRO
    JJ=YRO
    IF(YRO.EQ.0)JJ=1
    IF(YRO.EQ.0)YRADJ=1
    DO 10 II=JJ,JJ+19
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IF(CONCRT.AND.((.NOT.VAULT.AND.(UGTANK.OR.IGTANK)).OR.
+(NOSECON.AND.AGTANK)))THEN
* SUBTRACT OFF THE CONCRETE RELEASES DUE TO ITS PERMEABILITY,
* SINCE THE 'FALNUM' VARIABLES DO NOT STORE THIS VALUE.
   DO 20934 L=1,NTK
      TVOLUME(II)=TVOLUME(II)-PERMREL(L)*12
   20934 CONTINUE
ENDIF
    IF(TVOLUME(II).NE.0)THEN
*    'TEMPFAL' IS THE NEW FAILURE COUNTER; ITS USED FOR THE NEW LEAK
*     VOLUME ESTIMATES.
      TEMPFAL=0
*   'VOLADJ' REDUCES THIS VOLUME FOR RUPTURES,DEFICIENCIES,SPILLS AND
*    IMMEDIATELY DETECTED LEAKS.
      TEMPVOL=TVOLUME(II)
*   SUMS UP NEW 'TVOLUME'.
      CALCVOL=0.
      DO 20 LL=1,FALNUM
        IF(FALNUM4(LL).EQ.1)THEN
*        SECONDARY CONTAINMENT FAILED
          IF((YRO.EQ.O.AND.II.GE.((FALNUM7(LL)-1)/12+1).AND.II.LE
+.((FALNUM3(LL)-1)/12+1)).OR.(YRO.NE.O.AND.(II-YRO+1).GE.((FALNUM7
+     (LL)-1)/12+1).AND.(II-YRO+1).LE.((FALNUM3(LL)-1)/12+1)))THEN
*     FAILURE OCCURRED THAT YEAR
             IF(INT(FALNUM1(LL)/1000).NE.3)THEN
*            THE FAILURE IS NOT A CORROSION LEAK.
*            CALCULATE 'FALTIME'(# OF HRS THE COMPONENT IS IN
*             THE FAILED STATE FOR THAT YEAR)
               IF((YRO.EQ.O.AND.II.GT.((FALNUM7(LL)-1)/12+1)).OR.(
           YRO.NE.O.AND.(II-YRO+1).GT.((FALNUM7(LL)-1)/12+1)))THEN
*            THE RELEASE STARTED BEFORE THE PRESENT YEAR.
                IF((YRO.EQ.O.AND.II.LT.((FALNUM3(LL)-1)/12+1))
+   .OR.(YRO.NE.O.AND.(II-YRO+1).LT.((FALNUM3(LL)-1)/12+1)))THEN
*                THE RELAEASE ENDED AFTER THE PRESENT YEAR
                  FALTIME=720.*24.
                ELSE
*                   THE  RELEASE ENDED BEFORE THE END OF THE PRESENT
YEAR
                  FALTIME=(FALNUM3(LL)*720.)-(II-YRADJ)*720.*12.
                ENDIF
              ELSE
*                THE RELEASE STARTED DURING THE PRESENT YEAR.
                IF((YRO.EQ.O.AND.II.LT.((FALNUM3(LL)-1)/12+1))
+  .OR.(YRO.NE.O.AND.(II-YRO+1).LT.((FALNUM3(LL)-1)/12+1)))THEN
*               THE RELEASE ENDED AFTER THE PRESENT YEAR.
               FALTIME=(II-YRADJ+1)*720.*12.-(FALNUM7(LL)-1)*720.
                ELSE
*                 THE RELEASE STARTED AND ENDED IN THE PRESENT YEAR.
                  FALTIME=FALNUM5(LL)
                ENDIF
              ENDIF
*       ADJUST  RELEASE  PROFILE  TO  REFLECT  THE AMOUNT OF UNTREATED
WASTE.
              CALL VOLADJ(TEMPVOL,(FALTIME*(FALNUM2(LL)/FALNUM5
+ (LL))),MOD(INT(FALNUM1(LL)/10),100),MOD(FALNUM1(LL),10),CALCVOL)
            ELSE
*             FAILURE IS A CORROSION LEAK
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11390                 FALTIME=FALNUM7(LL)-FALNUM3(LL)+1
11395                 IF(FALTIME.EQ.1)THEN
11400*               LEAK LASTED .LE.  1 MONTH , RATE NEVER CHANGED
11405                   FALTIME=FALNUM5(LL)
11410                   CALL VOLADJ(TEMPVOL,(FALTIME*(FALNUM2(LL)/FALNUM5
11415+(LL))),MOD(INT(FALNUM1(LL)/10),100),MOD(FALNUM1(LL),10),CALCVOL)
11420                 ELSE
11425*                   LEAK LASTED MORE THAN A MONTH
11430                   TEMPFAL=TEMPFAL+1
11435                   FALTMP1(TEMPFAL)=FALNUM1(LL)
11440                   FALTMP2(TEMPFAL)=FALNUM2(LL)
11445                   FALTMP3(TEMPFAL)=FALNUM3(LL)
11450                   FALTMP5(TEMPFAL)=FALNUM5(LL)
11455                   FALTMP7(TEMPFAL)=FALNUM7(LL)
11460                 ENDIF
11465               ENDIF
11470             ENDIF
11475           ENDIF
11480         20 CONTINUE
11485         IF(TEMPVOL.GT.0)THEN
11490*        AT THIS POINT OF THE ROUTINE 'TEMPVOL' SHOULD CONTAIN
11495*     THE LONG LEAKS(>MONTH).  IF 'TEMPVOL' IS NEGATIVE IT IS
11500*     ASSUMED THAT THE LONG LEAKS ARE VERY MINOR CONTRIBUTORS
11505*     TO THE ANNUAL RELEASE VOLUME -- THESE VOLUMES ARE NOT ADDED TO
11510*     'CALCVOL' (THE NEW TVOLUME).
11515*       'TOTALLK' SUMS UP THE TOTAL RELEASE VOLUME OF THE LONG
11520*      LEAKS USING THE 'FALTMP' VARIABLES.
11525           TOTALLK=0.
11530           DO 30 LL=1,TEMPFAL
11535             IF((YRO.EQ.O.AND.II.GT.((FALTMP7(LL)-1)/12+1)).OR.(YRO
11540+        .NE.O.AND.(II-YRO+1).GT.((FALTMP7(LL)-1)/12+1)))THEN
11545*            THE RELEASE STARTED BEFORE THE PRESENT YEAR
11550               IF((YRO.EQ.O.AND.II.LT.((FALTMP3(LL)-1)/12+1)).OR.(
11555+        YRO.NE.O.AND.(II-YRO+1).LT.((FALTMP3(LL)-1)/12+1)))THEN
11560*              THE RELEASE ENDED AFTER THE PRESENT YEAR.
11565                 FALTIME=720.*24.
11570               ELSE
11575                 FALTIME=(FALTMP3(LL)*720.)-(II-YRADJ)*720.*12.
11580               ENDIF
11585             ELSE
11590*             THE RELEASE STARTED DURING THE PRESENT YEAR.
11595               IF((YRO.EQ.O.AND.II.LT.((FALTMP3(LL)-1)/12+1)).OR.(
11600+         YRO.NE.O.AND.(II-YRO+1).LT.((FALTMP3(LL)-1)/12+1)))THEN
11605*             THE RELEASE ENDED AFTER THE PRESENT YEAR.
11610               FALTIME=(II-YRADJ+1)*720.*12.-(FALTMP7(LL)-1)*720.
11615               ELSE
11620*                THE RELEASE STARTED AND ENDED IN THE SAME YEAR.
11625                 FALTIME=FALTMP5(LL)
11630               ENDIF
11635             ENDIF
11640*                 CALCULATE THE LEAK VOLUME RELEASED FOR THAT YEAR.
11645             FALTMP2(LL)=FALTIME*FALTMP2(LL)/FALTMP5(LL)
11650             TOTALLK=TOTALLK+FALTMP2(LL)
11655           30 CONTINUE
11660           DO 40 LL=1,TEMPFAL
11665             CALL VOLADJ(TEMPVOL,(FALTMP2(LL)*TEMPVOL/TOTALLK),MOD
11670+        (INT(FALTMP1(LL)/10),100),MOD(FALTMP1(LL),10),CALCVOL)
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        40 CONTINUE
       ENDIF
*          STORE NEW RELEASE VOLUME NUMBER.
       TVOLUME(II)=CALCVOL
     ENDIF
*  ADD THE RELEASE VOLUMES DUE TO CONCRETE PERMEABILITY
* BACK INTO THE RELEASE PROFILE.
 IF(CONCRT.AND.((.NOT.VAULT.AND.(UGTANK.OR.IGTANK)).OR.
+(NOSECON.AND.AGTANK)))THEN
    DO 68543 L=1,NTK
    IF(L.EQ.1)THEN
       IF(DISTILL)THEN
       TVOLUME(II)=TVOLUME(II)+PERMREL(L)*12*DVOLFR
       ELSE
       TVOLUME(II)=TVOLUME(II)+PERMREL(L)*12
       ENDIF
       ENDIF
       IF(L.EQ.2)THEN
       IF(DISTILL)THEN
       TVOLUME(II)=TVOLUME(II)+PERMREL(L)*12
       ELSE
       TVOLUME(II)=TVOLUME(II)+PERMREL(L)*12*(1-TRTEFF)
       ENDIF
       ENDIF
       IF(L.EQ.3)THEN
       TVOLUME(II)=TVOLUME(II)+PERMREL(L)*12*(1-TRTEFF)
       ENDIF
  68543 CONTINUE
 ENDIF
   10 CONTINUE
 ENDIF
 DO 45962 L=1,NYEAR
*   CONVERT THE RELEASE PROFILE FROM GALLONS TO CUBIC METERS
    TVOLUME(L)=TVOLUME(L)*.003785
 45962 CONTINUE
* OUTPUT THE RELEASE PROFILE RESULTS.
 IF(YRO.EQ.O)THEN
 WRITE(14,614)  I,DBS*.3048,1.,TVOLUME(1),
+TVOLUME(2),TVOLUME(3),TVOLUME(4),TVOLUME(5),TVOLUME(6),
+TVOLUME(7),TVOLUME(8),TVOLUME(9)
 WRITE(14,615) (TVOLUME(II),II=10,20)
 ELSE
 WRITE(14,614)  I,DBS*.3048,1.,TVOLUME(YRO),
+TVOLUME(YRO+1),TVOLUME(YRO+2),TVOLUME(YRO+3),TVOLUME(YRO+4),
+TVOLUME(YRO+5),TVOLUME(YRO+6),TVOLUME(YRO+7),TVOLUME(YRO+8)
 WRITE(14,615) (TVOLUME(II),II=YRO+9,YRO+19)
 ENDIF
 66614 FORMAT(26(1X,I2),1X,I3)
* OUTPUT THE FREQUENCY TABLE RESULTS
 WRITE(15,66614)  YREVP(8),YREVP(7),YREVP(6),YREV(8),YREV(7),
+YREV(6),YREV(5),YREV(11),YREV(10),YREV1(4),YREV(4),
+YREVW(9),YREVP(9),YREV(9),YREVW1(3),
+YREVW(3),YREVP1(3),YREVP(3),YREV1(3),YREV(3),YREVP1(2),
+YREVP(2),YREV1(2),YREV(2),YREV(1),(FALNUM7(1)/12)+1,I
     OTNONLK=1
    IREPFLG=0
    IF(FALNUM.NE.O)THEN
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11960  IF(FALNUM.EQ.1)GO TO 527
11965* OUTPUT THE DUMP FILE RESULTS
11970  DO 526 II=1,FALNUM-1
11975  WRITE(8,931)I,II,FALNUM7(II),FALNUM5(II),FALNUM3(II),
11980+FALNUM2(II)/FALNUM5(II),INT(MOD(FALNUM1(II),1000)/10)
11985+,MOD(FALNUM1(II),10),INT(FALNUM1(II)/1000),FALNUM4(II)
11990+       ,FALNUM6(II)
11995 IF(IREPFLG.EQ.0)THEN
12000 IF((INT(MOD(FALNUM1(II),1000)/10).EQ.3).OR.(INT(MOD(FALNUM1(II)
12005+  ,1000)/10).EQ.6))THEN
12010*  YEAR OF FIRST TANK REPLACEMENT
12015     AGTK1ST(I)=FALNUM3(II)/12.+YRO-1
12020     AGTKREP=AGTKREP+1
12025     IREPFLG=1
12030     ENDIF
12035 ENDIF
12040 IF(FALNUM4(II).EQ.1)THEN
12045  IF(II.NE.1)THEN
12050    DO 380 JKL=1,II-1
12055      IF(FALNUM3(JKL).EQ.FALNUM3(II).AND.FALNUM4(JKL).EQ.1)GO TO 381
12060    380 CONTINUE
12065  ENDIF
12070  IPIPFLG=0
12075  ICORFLG=0
12080 IF((IPIPFLG.EQ.0).AND.(INT(MOD(FALNUM1(II),1000)/10).EQ.1))THEN
12085*    NUMBER OF FACILITIES WITH A PIPE FAILURE INCIDENT
12090     AGPIPNO=AGPIPNO+1
12095     IPIPFLG=1
12100  ENDIF
12105  IF((ICORFLG.EQ.0).AND.(INT(FALNUM1(II)/1000).EQ.3))THEN
12110* NUMBER OF FACILITIES WITH A CORROSION INCIDENT
12115      AGCORNO=AGCORNO+1
12120      ICORFLG=1
12125  ENDIF
12130  SIZD=FALNUM2(II)
12135  IDETD=FALNUM5(II)
12140  DO 382 JLK=II+1,FALNUM
12145     IF(FALNUM3(JLK).EQ.FALNUM3(II).AND.FALNUM4(JLK).EQ.1)THEN
12150       SIZD=SIZD+FALNUM2(JLK)
12155       IDETD=MAX(REAL(IDETD),FALNUM5(JLK))
12160 IF((IPIPFLG.EQ.0).AND.(INT(MOD(FALNUM1(JLK),1000)/10).EQ.1))
12165+      THEN
12170     AGPIPNO=AGPIPNO+1
12175     IPIPFLG=1
12180  ENDIF
12185  IF((ICORFLG.EQ.0).AND.(INT(FALNUM1(JLK)/1000).EQ.3))THEN
12190      AGCORNO=AGCORNO+1
12195      ICORFLG=1
12200  ENDIF
12205     ENDIF
12210  382 CONTINUE
12215*AGGREGATE NUMBER OF RELEASE INCIDENTS  NOT  DETECTED  BY  THE  FINAL
YEAR.
12220 IF((FALNUM3(II).EQ.(J*12)).AND.(.NOT.TANKREP).AND.(FALNUM6(II).EQ.
12225+           'ND'))AGNYFAL=AGNYFAL+1
12230*   CALCULATE DISTIBUTION TABLES FOR RELEASE VOLUMES
12235*   AND DETECTION TIMES.
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12240 CALL SIZDIST(SIZD)
12245 CALL DETDIST(IDETD)
12250 AGGFAIL=AGGFAIL+1
12255 381 CONTINUE
12260 OTNONLK=0
12265 ENDIF
12270     526 CONTINUE
12275 527 WRITE(8,932) I,FALNUM,FALNUM7(FALNUM),FALNUM5
12280+(FALNUM),FALNUM3(FALNUM),FALNUM2(FALNUM)
12285+/FALNUM5(FALNUM),INT(MOD(FALNUM1(FALNUM),1000)/10),MOD(
12290+FALNUM1(FALNUM),10),INT(FALNUM1(FALNUM)/1000),
12295+  FALNUM4(FALNUM),FALNUM6(FALNUM)
12300 IF(IREPFLG.EQ.0)THEN
12305 IF((INT(MOD(FALNUM1(FALNUM),1000)/10).EQ.3).OR.(INT(MOD(
12310+FALNUM1(FALNUM),1000)/10).EQ.6))THEN
12315     AGTK1ST(I)=FALNUM3(FALNUM)/12.+YR0-1
12320     IREPFLG=1
12325     AGTKREP=AGTKREP+1
12330    ENDIF
12335 ENDIF
12340 IF(FALNUM4(FALNUM).EQ.1)THEN
12345    IF(FALNUM.NE.1)THEN
12350      DO 383 LKJ=1,FALNUM-1
12355   IF(FALNUM3(LKJ).EQ.FALNUM3(FALNUM).AND.FALNUM4(LKJ).EQ.1)GO TO
12360+                   384
12365       383 CONTINUE
12370    ENDIF
12375*AGGREGATE NUMBER OF RELEASE INCIDENTS CAUSED BY CORROSION
12380 IF(INT(FALNUM1(FALNUM)/1000).EQ.3)AGCORNO=AGCORNO+1
12385 IF(INT(MOD(FALNUM1(FALNUM),1000)/10).EQ.1)AGPIPNO=AGPIPNO+1
12390*AGGREGATE  NUMBER  OF  RELEASE  INCIDENTS  NOT DETECTED BY THE FINAL
YEAR.
12395 IF((FALNUM3(FALNUM).EQ.(J*12)).AND.(.NOT.TANKREP).AND.(FALNUM6(
12400+        FALNUM).EQ.'ND'))AGNYFAL=AGNYFAL+1
12405 CALL SIZDIST(FALNUM2(FALNUM))
12410 CALL DETDIST(INT(FALNUM5(FALNUM)))
12415 AGGFAIL=AGGFAIL+1
12420 384 CONTINUE
12425 OTNONLK=0
12430 ENDIF
12435 NONLEAK=NONLEAK+OTNONLK
12440 ELSE
12445* NON-LEAKING FACILITY
12450     NONLEAK=NONLEAK+1
12455           ENDIF
12460 IF(AGTK1ST(I).EQ.0)AGTK1ST(I)=100.0
12465 TVOL1=TVOL1+VOL1
12470*CUMULATIVE AGGREGATE RELEASE VOLUME
12475 IF(VAULT.OR.PIPSEC.OR.CONCPAD.OR.ASPHPAD)THEN
12480 CUMREL=CUMREL+VOL1+TRVOL
12485 ELSE
12490 CUMREL=CUMREL+VOL1+TRVOL+TCLVOL
12495 ENDIF
12500 AGTKAGE=AGTKAGE+IYRNUM
12505 ENDIF
12510 931 FORMAT(I4,1X,I2,1X,I3,1X,F8.1,1X,I3,1X,F11.6,1X,I2,1X,I1,1X,
12515+I1,1X,I1,1X,A2)
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12520 932 FORMAT(I4,1X,I2,1X,I3,1X,F8.1,1X,I3,1X,F11.6,1X,I2,1X,I1,1X
12525+I1,1X,I1,1X,A2)
12530 IF(FALNUM.GT.0)THEN
12535    DO 620 II=1,FALNUM
12540       IF(FALNUM6(II).EQ.'ND')THEN
12545* AGGREGATE NUMBER OF UNDETECTED RELEASES.
12550          AGUNDET(IYRNUM)=AGUNDET(IYRNUM)+1
12555          GO TO 621
12560       ENDIF
12565     620 CONTINUE
12570     621 CONTINUE
12575 ENDIF
12580 ENDIF
12585  IF(YRO.NE.0.AND.IYRNUM.EQ.(YRO-1))CALL RESTART
12590     IF(YRO.NE.0.AND.IYRNUM.EQ.(YRO-1))COUNT1=COUNT1+1
12595   110 CONTINUE
12600 TTCVOL=TTCVOL+TCLVOL
12605 62 CONTINUE
12610 SEED=SEED+MM+(78*NYEAR)
12615 100 CONTINUE
12620  WRITE(13,612)NYEAR
12625 WRITE(10,713) 'TOTAL CLEANUP VOLUME FOR ALL FAC.=',TTCVOL
12630 WRITE(12,7080)TITLE
12635 WRITE(12,7080)TITLE1
12640 7080 FORMAT(A110)
12645 WRITE(12,1082) '1','2','3','4','5','6','7','8','9'
12650 WRITE(12,1081)'CUMULAT','# OF','# OF','# OF REL','# NOT','#OF FAC',
12655+'# REL W/','VOLUM IN',
12660+'# OF REL'
12665 WRITE(12,1081)'RELEASE','NON-LEAK','RELEASE','IN W/','DETECTED',
12670+ 'W/ TANK',
12675+'FLASH','UNSAT','IN W/ '
12680 WRITE(12,1081)' ','FACIL','INCID','CORROS','BY END','REPLAC',
12685+'POINT','ZONE','PI-FAIL'
12690 WRITE(12,1084)CUMREL,NONLEAK,AGGFAIL,AGCORNO,AGNYFAL,AGTKREP,
12695+AGFLASH,AGUNSAT,AGPIPNO
12700 IF(YRO.EQ.0)AGPOPUL=FAC
12705 IF(YRO.NE.0)THEN
12710   WRITE(12,41)'33','34','35'
12715   WRITE(12,42)'# OF TKS','# OF TKS','AVERAGE'
12720   WRITE(12,42)'LKING BY','IN EXIST','TANK'
12725   WRITE(12,42)'YRO UNDET','POPULAT','AGE'
12730   WRITE(12,43)AGTKLK,AGPOPUL,AGTKAGE/REAL(AGPOPUL)
12735 ENDIF
12740 41 FORMAT(3(A6,4X))
12745 42 FORMAT(3(A9,1X))
12750 43 FORMAT(2(I9,1X),F6.1)
12755 1081 FORMAT(9(A9,1X))
12760 1082 FORMAT(9(A6,4X))
12765 1084 FORMAT(E10.4,6(I9,1X),E10.4,1X,I9)
12770 WRITE(12,1086)'SIZE DISTRIBUTION OF RELEASE INCIDENTS(GALLONS)'
12775 WRITE(12,1087)'NUMBER','SIZE'
12780 WRITE(12,1088)NSIZE(1),'<1'
12785 WRITE(12,1088)NSIZE(2),'1-10'
12790 WRITE(12,1088)NSIZE(3),'10-25'
12795 WRITE(12,1088)NSIZE(4),'25-100'
12800 WRITE(12,1088)NSIZE(5),'100-500'
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12805 WRITE(12,1088)NSIZE(6),'500-1000'
12810 WRITE(12,1088)NSIZE(7),'1000-3000'
12815 WRITE(12,1088)NSIZE(8),'3000-5000'
12820 WRITE(12,1088)NSIZE(9),'5000-7000'
12825 WRITE(12,1088)NSIZE(10),'7000-10000'
12830 WRITE(12,1088)NSIZE(11),'10000-20000'
12835 WRITE(12,1088)NSIZE(12),'20000-30000'
12840 WRITE(12,1088)NSIZE(13),'30000-60000'
12845 WRITE(12,1088)NSIZE(14),'>60000'
12850 1086 FORMAT(A50)
12855 1087 FORMAT(A6,3X,A12)
12860 1088 FORMAT(I6,3X,A12)
12865 WRITE(12,1086)'DISTRIBUTION OF DETECTION TIMES'
12870 WRITE(12,1087)'NUMBER','SIZE'
12875 WRITE(12,1088)DETSIZE(1),'<DAY'
12880 WRITE(12,1088)DETSIZE(2),'DAY-WEEK'
12885 WRITE(12,1088)DETSIZE(3),'WEEK-MONTH'
12890 WRITE(12,1088)DETSIZE(4),'MONTH-6 MONTHS'
12895 WRITE(12,1088)DETSIZE(5),'6 MONTHS-YEAR'
12900 WRITE(12,1088)DETSIZE(6),'1-3YEARS'
12905 WRITE(12,1088)DETSIZE(7),'3-5YEARS'
12910 WRITE(12,1088)DETSIZE(8),'5-10YEARS'
12915 WRITE(12,1088)DETSIZE(9),'10-15YEARS'
12920 WRITE(12,1088)DETSIZE(10),'15-20YEARS'
12925 WRITE(12,1088)DETSIZE(11),'20-25YEARS'
12930 WRITE(12,1088)DETSIZE(12),'>25 YEARS'
12935*WRITE(12,1086)'TIME OF INITIAL TANK REPLACEMENT'
12940*WRITE(12,1089)'FAC','YEAR'
12945*AGGAGE=0.
12950*ICT=0
12955*DO 5022 I=1,FAC
12960*WRITE(12,1090)I,AGTK1ST(I)
12965*IF((AGTK1ST(I).GT.0.).AND.(AGTK1ST(I).LT.100.))THEN
12970*   ICT=ICT+1
12975*AGGAGE=AGGAGE+AGTK1ST(I)
12980*ENDIF
12985*5022 CONTINUE
12990*   AVGAGE=AGGAGE/REAL(ICT)
12995*WRITE(12,1093)'MEAN TIME TO FIRST TANK FAILURE',AVGAGE
13000*1093 FORMAT(/,A31,1X,F6.1,/)
13005*1090 FORMAT(I4,3X,F6.1)
13010*1089 FORMAT(A3,3X,A6)
13015 WRITE(12,21113)'AGGREGATE NUMBER OF UNDETECTED RELEASES/YEAR'
13020 WRITE(12,21111)'YEAR','# UNDETECTED RELEASES'
13025 DO 2113 III=1,NYEAR-1
13030 WRITE(12,21112)III,AGUNDET(III)
13035 2113 CONTINUE
13040 WRITE(12,21112)NYEAR,AGNYFAL
13045 21112 FORMAT(I3,3X,I6)
13050 21111 FORMAT(A4,3X,A21)
13055 21113 FORMAT(A60)
13060 END
13065 SUBROUTINE ANCILOS(YR)
13070*   'ANCILOS' CALLS THE ROUTINES THAT ESTIMATE ANY
13075* ANCILLARY EQUIPMENT FAILURES DUE TO LEAKS, RUPTURES OR
13080*DEFICEINCIES.  IT ALSO CHECKS WHETHER THE PIPE SECONDARY CONTAINMENT
13085* IS IN THE FAILED STATE.  IF IT IS IN A FAILED STATE IT
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13090* SAMPLES THE MONTH OF FAILURE.
13095 COMMON/LOOPCT/NPI,NTK
13100 INTEGER NPI,NTK
13105 COMMON/IYRNO/IYRNUM
13110 INTEGER IYRNUM
13115 COMMON/PI2TIM/DIKTIM(5),CURTIM(5),PASPTIM(5),PCOPTIM(5),PLINTIM(5)
13120 REAL DIKTIM,CURTIM,PASPTIM,PCOPTIM,PLINTIM
13125 LOGICAL PCFAIL
13130 COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
13135 LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
13140 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
13145 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
13150 COMMON/ANC/ANCIL
13155 LOGICAL ANCIL
13160 COMMON/CONT/UGCONT(3),AGCONT(3),PIPCONT(5),NUGCONT(3),NAGCONT(3)
13165+,NPICONT(5)
13170 INTEGER UGCONT,AGCONT,PIPCONT,NUGCONT,NAGCONT,NPICONT
13175 COMMON/PIPCON/DIKE,CURB,ASPAD,COPAD,PLINER
13180 LOGICAL DIKE,CURB,ASPAD,COPAD,PLINER
13185 INTEGER YR
13190 ANCIL=.TRUE.
13195 IF(UGPIPE)THEN
13200*    CHECK TO SEE IF THERE ARE ANY ANCILLARY FAILURES IN THAT YEAR.
13205     CALL LEAKRUP(ANCIL,YR)
13210    ELSE
13215*    AG PIPES
13220*    CHECK TO SEE IF THERE ARE ANY ANCILLARY FAILURES IN THAT YEAR.
13225     CALL LEAKRUP(ANCIL,YR)
13230     PCFAIL=.FALSE.
13235     IF(PIPSEC)THEN
13240*       CHECK FOR ANY PIPE CONTAINMENT FAILURES.
13245     DO 57913 L=1,NPI
13250        PCFAIL=.FALSE.
13255     IF(NPICONT(L).EQ.0)THEN
13260     IF(DIKTIM(L).LE.IYRNUM)PCFAIL=.TRUE.
13265     IF(CURTIM(L).LE.IYRNUM)PCFAIL=.TRUE.
13270     IF(PASPTIM(L).LE.IYRNUM)PCFAIL=.TRUE.
13275     IF(PCOPTIM(L).LE.IYRNUM)PCFAIL=.TRUE.
13280     IF(PLINER)THEN
13285      IF(PLINTIM(L).LE.IYRNUM)THEN
13290       IF((DIKE.OR.CURB.OR.ASPAD.OR.COPAD).AND.PCFAIL)THEN
13295        PCFAIL=.TRUE.
13300       ELSEIF(.NOT.(DIKE.OR.CURB.OR.ASPAD.OR.COPAD))THEN
13305        PCFAIL=.TRUE.
13310       ELSE
13315        PCFAIL=.FALSE.
13320       ENDIF
13325      ELSE
13330       PCFAIL=.FALSE.
13335      ENDIF
13340     ENDIF
13345        IF(PCFAIL)CALL FTIME(PIPCONT(L))
13350     ENDIF
13355     57913 CONTINUE
13360     ENDIF
13365 ENDIF
13370 ANCIL=.FALSE.
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13375 RETURN
13380 END
13385 REAL FUNCTION FNB(P)
13390*   THIS FUNCTION SAMPLES A BINOMIAL DISTRIBUTION
13395       COMMON/AX/IY
13400 REAL P
13405       X=0
13410       R=RAN(IY)
13415       IF(R-P)5,5,10
13420    5  X=X+1
13425   10 CONTINUE
13430       FNB=X
13435       RETURN
13440       END
13445 SUBROUTINE FTIME(FCOMP)
13450*   THIS SUBROUTINE RETURNS A MONTH OF FAILURE(1 ..  12)
13455 INTEGER FCOMP
13460 FCOMP=INT(FNU(0.,11.99))+1
13465 RETURN
13470 END
13475 SUBROUTINE LEAKRUP(ANCIL,YR)
13480*    THIS ROUTINE CALLS THE ROUTINES THAT CHECK FOR COMPONENT
13485* RUPTURE,LEAK OR DEFICIENCY.
13490 COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
13495 LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
13500 COMMON/CONCTM/CONCTIM(3)
13505 REAL CONCTIM
13510 COMMON/THICKNS/PIPEI(5),PUMPI(5),GASKI(5)
13515 COMMON/EXTHICK/PIPEE(5),PUMPE(5),GASKE(5),PIPE2E(5),PIPE2I(5)
13520 REAL PIPEI,PUMPI,GASKI,PDIAM
13525 REAL PIPEE,PUMPE,GASKE,PIPE2E,PIPE2I
13530 COMMON/PIPELK/INTLK(5),PIPAGE(5),NUMLK(5),PRAN(5)
13535 INTEGER INTLK,NUMLK,PIPAGE
13540 REAL PRAN
13545 COMMON/LOOPCT/NPI,NTK
13550 INTEGER NPI,NTK
13555 COMMON/IYRNO/IYRNUM
13560 COMMON/PIPETIM/PIPDEF(5),WLDDEF(5),GSKDEF(5),PIPLK(5),
13565+GSKLK(5),RUPPIP(5)
13570 COMMON/TANKTIM/TNKDEF(3),TNKLK(3),RUPTNK(3)
13575 COMMON/SURFTIM/LOOSE,HOSPORT,PMPLK(5),RUPWLD(5),VENT
13580 COMMON/SUFTIM/HOSPERM,DRANPMP(5)
13585
13590 INTEGER PIPDEF,WLDDEF,GSKDEF,PIPLK,GSKLK,RUPPIP
13595 INTEGER TNKDEF,TNKLK,RUPTNK
13600 INTEGER LOOSE,HOSPORT,PMPLK,RUPWLD,VENT
13605 INTEGER HOSPERM,DRANPMP
13610 COMMON/RUPPROB/TNKRUP2(2),TNKRUP(2),WLDRUP(2),PIPRUP(2),PORTHOS(2)
13615 COMMON/RUPPR1/PERMHOS(2),PMPDRAN(2)
13620 REAL PERMHOS,PMPDRAN
13625 REAL TNKRUP2,TNKRUP,WLDRUP,PIPRUP,PORTHOS
13630 REAL TRUP,TRUP2,WRUP,PRUP,PRUP2
13635 LOGICAL ANCIL
13640 COMMON/FIDITYP/FILLING,DISCHRG
13645 INTEGER FILLING,DISCHRG
13650 COMMON/PUMPTYP/PORTFP,PORTDP
13655 LOGICAL PORTFP,PORTDP
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13660 INTEGER IYRNUM,YR
13665 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
13670 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
13675 COMMON/CONNECT/WELDFLG,GASKET
13680 LOGICAL WELDFLG,GASKET
13685 COMMON/DEFFLAG/DLTNK(3),DDTNK(3),DRTNK(3),DLGSK(5),DDGSK(5),
13690+DDWLD(5),DRWLD(5),DLPIP(5),DRPIP(5),DDPIP(5),DLPMP(5),DALL
13695 LOGICAL DLTNK,DDTNK,DRTNK,DLGSK,DDGSK,DDWLD,DRWLD,DLPIP,DRPIP,
13700+DDPIP,DLPMP,DALL
13705 COMMON/VAPPRB/VAPSENS,VSENSOR
13710 REAL VAPSENS,VSENSOR
13715 INTEGER FALNUM,FALNUM1,FALNUM3,FALNUM4,FALNUM7
13720 COMMON/FALNUM/FALNUM,FALNUM1(100),FALNUM2(100),FALNUM3(100),
13725+  FALNUM4(100),FALNUM5(100),FALNUM7(100)
13730 COMMON/FALNUM6/FALNUM6(100)
13735 CHARACTER FALNUM6*2
13740 REAL FALNUM2,FALNUM5
13745 COMMON/ITHICK/IPIPE(5),IPUMP(5),ITANK(3),IGASK(5),ITANK2(3)
13750 REAL IPIPE,IPUMP,ITANK,IGASK,ITANK2
13755 COMMON/EXTHI/TANKE(3),TANK2E(3)
13760 REAL TANKE,TANK2E
13765 COMMON/THICK/TANKI(3),TANK2I(3)
13770 REAL TANKI,TANK2I
13775 COMMON/ALARM/INTERST(5,2),INTER,PIINTER(5,2),PINTER
13780 REAL INTERST,INTER,PIINTER,PINTER
13785 COMMON/WALL/TK2WALL,PI2WALL
13790 LOGICAL TK2WALL,PI2WALL
13795 COMMON/MONIT/MONMETH(7),PIPMON
13800 LOGICAL MONMETH,PIPMON
13805 COMMON/COUNT/NPIPDEF(5),NWLDDEF(5),NGSKDEF(5),NPIPLK(5),NGSKLK(5),
13810+NRUPPIP(5),NPMPLK(5),NRUPWLD(5),NTNKLK(3),NTNKDEF(3),NRUPTNK(3)
13815 REAL NPIPDEF,NWLDDEF,NGSKDEF,NPIPLK,NGSKLK,NRUPPIP,NPMPLK,NRUPWLD,
13820+     NTNKLK,NTNKDEF,NRUPTNK
13825 LOGICAL PIREPAR,TKREPAR,PMREPAR
13830 COMMON/PITRE/PIREPAR(5),TKREPAR(3),PMREPAR(5)
13835 LOGICAL WALL2,TKFAIL
13840 LOGICAL PWALL2,PIFAIL
13845 INTEGER RUPTNK2,RUPPIP2
13850 WALL2=.FALSE.
13855 TKFAIL=.FALSE.
13860 IF(.NOT.ANCIL)THEN
13865 DO 281 L=1,NPI
13870 IF(IYRNUM.EQ.1)THEN
13875*IN YEAR 1, CALL ROUTINE THAT SAMPLES FOR INSTALL DEFICEINCIES.
13880 CALL DEFICNT(L,YR,1)
13885 CALL DEFICNT(L,YR,2)
13890 CALL DEFICNT(L,YR,4)
13895 CALL DEFICNT(L,YR,5)
13900 DALL=.FALSE.
13905 ENDIF
13910 IF(IYRNUM.NE.1)THEN
13915*  WHEN A COMPONENT IS REPLACED, CALL ROUTINE THAT SAMPLES
13920*  FOR INSTALLATION DEFICEINCIES.
13925     IF(DALL)THEN
13930 CALL DEFICNT(L,YR,1)
13935 CALL DEFICNT(L,YR,2)
13940 CALL DEFICNT(L,YR,4)
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CALL DEFICNT(L,YR,5)
    ENDIF
    IF(DRPIP(L))THEN
        CALL DEFICNT(L,YR,1)
        DRPIP(L)=.FALSE.
    ENDIF
    IF(DLPIP(L))THEN
        CALL DEFICNT(L,YR,1)
        DLPIP(L)=.FALSE.
    ENDIF
    IF(DDPIP(L))THEN
        CALL DEFICNT(L,YR,1)
        DDPIP(L)=.FALSE.
    ENDIF
    IF(DDGSK(L))THEN
        CALL DEFICNT(L,YR,5)
        DDGSK(L)=.FALSE.
    ENDIF
    IF(DLGSK(L))THEN
        CALL DEFICNT(L,YR,5)
        DLGSK(L)=.FALSE.
    ENDIF
    IF(DRWLD(L))THEN
        CALL DEFICNT(L,YR,4)
        DRWLD(L)=.FALSE.
    ENDIF
    IF(DDWLD(L))THEN
        CALL DEFICNT(L,YR,4)
        DDWLD(L)=.FALSE.
    ENDIF
    IF(DLPMP(L))THEN
        CALL DEFICNT(L,YR,2)
        DLPMP(L)=.FALSE.
    ENDIF
ENDIF
281 CONTINUE
DO 2810 L=1,NTK
IF(IYRNUM.EQ.1)THEN
    CALL DEFICNT(L,YR,3)
    DALL=.FALSE.
ENDIF
IF(IYRNUM.NE.1)THEN
IF(DALL)THEN
    CALL DEFICNT(L,YR,3)
    DALL=.FALSE.
ENDIF
IF(DDTNK(L))THEN
    CALL DEFICNT(L,YR,3)
    DDTNK(L)=.FALSE.
ENDIF
IF(DRTNK(L))THEN
    CALL DEFICNT(L,YR,3)
    DRTNK(L)=.FALSE.
ENDIF
IF(DLTNK(L))THEN
    CALL DEFICNT(L,YR,3)
    DLTNK(L)=.FALSE.
```

```
14230 ENDIF
14235 ENDIF
14240*  SAMPLE FOR RUPTURE FAILURES.
14245 IF(CONCRT)THEN
14250     IF(CONCTIM(L).LE.IYRNUM)THEN
14255         CALL FTIME(RUPTNK(L))
14260     ENDIF
14265 ENDIF
14270 IF(.NOT.CONCRT)THEN
14275     IF(.NOT.TK2WALL)THEN
14280     TRUP=RUPTURE(3,IYRNUM)
14285     IF(TRUP.EQ.1)THEN
14290         CALL FTIME(RUPTNK(L))
14295     ENDIF
14300     ENDIF
14305 IF(TK2WALL)THEN
14310* ASSUME 50 REDUCTION IN PROB.  OF INNER WALL FAILING
14315 TRUP=RUPTURE(3,IYRNUM)*FNB(.50)
14320 IF(TRUP.EQ.1)THEN
14325 CALL FTIME(RUPTNK(L))
14330 TKFAIL=.TRUE.
14335     IF(NRUPTNK(L).EQ.0)THEN
14340*  INTERSTITIAL MONITORING
14345         IF(MONMETH(2)) THEN
14350            INTERST(L,2)=FNB(INTERST(L,1))
14355            IF(INTERST(L,2).EQ.0)  THEN
14360                CALL REPLAC(3,1)
14365 VAPSENS=VSENSOR
14370                FALNUM=FALNUM+1
14375                FALNUM1(FALNUM)=2030+L
14380                  FALNUM7(FALNUM)=(YR-1)*12+RUPTNK(L)
14385                FALNUM2(FALNUM)=1.
14390                FALNUM3(FALNUM)=((YR-1)*12)+RUPTNK(L)
14395                FALNUM4(FALNUM)=2
14400                FALNUM6(FALNUM)='IS'
14405                TANKI(L)=ITANK(L)
14410                TANKE(L)=ITANK(L)
14415                TANK2I(L)=ITANK(L)
14420                TANK2E(L)=ITANK(L)
14425                WALL2=.FALSE.
14430                TKFAIL=.FALSE.
14435                TKREPAR(L)=.TRUE.
14440                NRUPTNK(L)=0
14445                RUPTNK(L)=0
14450                RUPTNK2=0
14455           ELSE
14460               INTERST(L,1)=1.0
14465           ENDIF
14470         ENDIF
14475     ENDIF
14480 ENDIF
14485 TRUP2=RUPTURE(3,IYRNUM)
14490 IF(TRUP.EQ.1)TRUP2=1
14495 IF(TRUP2.EQ.1)THEN
14500       WALL2=.TRUE.
14505       CALL FTIME(RUPTNK2)
14510       IF(TRUP.EQ.1)GO TO 11961
```

```
    IF (NRUPTNK (L) .EQ.0) THEN
*  INTERSTITIAL MONITORING
       IF (MONMETH (2))  THEN
         INTERST (L,2) =FNB (INTERST (L,1))
         IF (INTERST (L,2) .EQ.0)  THEN
            CALL REPLAC (3,1)
VAPSENS=VSENSOR
            FALNUM=FALNUM+1
            FALNUM1 (FALNUM) =2030+L
            FALNUM7 (FALNUM) = (YR-1) *12+RUPTNK2
            FALNUM2 (FALNUM) =1
            FALNUM3 (FALNUM) = ((YR-1) *12) +RUPTNK2
            FALNUM4 (FALNUM) =2
            FALNUM6 (FALNUM) ='IS'
            TANKI (L) =ITANK (L)
            TANKE (L) =ITANK (L)
            TANK2I (L) =ITANK (L)
            TANK2E (L) =ITANK (L)
            WALL2=.FALSE.
            TKFAIL=.FALSE.
            TKREPAR (L) =.TRUE.
            NRUPTNK (L) =0
            RUPTNK (L) =0
            RUPTNK2=0
       ELSE
          INTERST (L,1) =1.0
       ENDIF
     ENDIF
   ENDIF
11961 CONTINUE
   ENDIF
ENDIF
IF (WALL2.AND.TKFAIL.AND. (NRUPTNK (L) .EQ.0)) THEN
   IF (RUPTNK (L) .LE.RUPTNK2.AND. (RUPTNK2.NE.0)) THEN
          RUPTNK (L) =RUPTNK2
  ELSE
   RUPTNK (L) =0
   ENDIF
ENDIF
ENDIF
2810 CONTINUE
ENDIF
IF (ANCIL) THEN
 DO 501 L=1,NPI
   IF (WELDFLG) THEN
   WRUP=RUPTURE (4,IYRNUM)
   IF (WRUP.EQ.1) THEN
      CALL FTIME (RUPWLD (L))
   ENDIF
   ENDIF
  IF (.NOT.PI2WALL) THEN
   PRUP=RUPTURE (1,IYRNUM)
   IF (PRUP.EQ.1) THEN
      CALL FTIME (RUPPIP (L))
   ENDIF
  ENDIF
IF (PI2WALL) THEN
```

```
14800 PWALL2=.FALSE.
14805 PIFAIL=.FALSE.
14810 RUPPIP(L)=0
14815 RUPPIP2=0
14820* ASSUME 50 REDUCTION IN PROB.  OF INNER WALL FAILING
14825 PRUP=RUPTURE(1,IYRNUM)*FNB(.50)
14830 IF(PRUP.EQ.1)THEN
14835 CALL FTIME(RUPPIP(L))
14840 PIFAIL=.TRUE.
14845    IF(NRUPPIP(L).EQ.0)THEN
14850*  INTERSTITIAL MONITORING
14855      IF(MONMETH(7)) THEN
14860         PIINTER(L,2)=FNB(PIINTER(L,1))
14865         IF(PIINTER(L,2).EQ.0) THEN
14870            CALL REPLAC(1,L)
14875            FALNUM=FALNUM+1
14880            FALNUM1(FALNUM)=2010+L
14885             FALNUM7(FALNUM)=(YR-1)*12+RUPPIP(L)
14890            FALNUM2(FALNUM)=1.
14895            FALNUM3(FALNUM)=((YR-1)*12)+RUPPIP(L)
14900            FALNUM4(FALNUM)=2
14905            FALNUM6(FALNUM)='IS'
14910            PIPEI(L)=IPIPE(L)
14915            PIPEE(L)=IPIPE(L)
14920            PIPE2I(L)=IPIPE(L)
14925            PIPE2E(L)=IPIPE(L)
14930       INTLK(L)=0
14935       PIPAGE(L)=0
14940       NUMLK(L)=0
14945       PRAN(L)=FNU(0.,2.)
14950            PWALL2=.FALSE.
14955            PIFAIL=.FALSE.
14960            PIREPAR(L)=.TRUE.
14965            NRUPPIP(L)=0
14970            RUPPIP(L)=0
14975            RUPPIP2=0
14980        ELSE
14985           PIINTER(L,1)=1.0
14990        ENDIF
14995      ENDIF
15000    ENDIF
15005 ENDIF
15010 PRUP2=RUPTURE(1,IYRNUM)
15015 IF(PRUP.EQ.1)PRUP2=1
15020 IF(PRUP2.EQ.1)THEN
15025       PWALL2=.TRUE.
15030       CALL FTIME(RUPPIP2)
15035       IF(PRUP.EQ.1)GO TO 21961
15040    IF(NRUPPIP(L).EQ.0)THEN
15045*  INTERSTITIAL MONITORING
15050       IF(MONMETH(7)) THEN
15055         PIINTER(L,2)=FNB(PIINTER(L,1))
15060         IF(PIINTER(L,2).EQ.0) THEN
15065            CALL REPLAC(1,L)
15070            FALNUM=FALNUM+1
15075            FALNUM1(FALNUM)=2010+L
15080            FALNUM7(FALNUM)=(YR-1)*12+RUPPIP2
```

```
            FALNUM2(FALNUM)=1.
            FALNUM3(FALNUM)=((YR-1)*12)+RUPPIP2
            FALNUM4(FALNUM)=2
            FALNUM6(FALNUM)='1S'
            PIPEI(L)=IPIPE(L)
            PIPEE(L)=IPIPE(L)
            PIPE2I(L)=IPIPE(L)
            PIPE2E(L)=IPIPE(L)
       INTLK(L)=0
       PIPAGE(L)=0
       NUMLK(L)=0
       PRAN(L)=FNU(0.,2.)
            PWALL2=.FALSE.
            PIFAIL=.FALSE.
            PIREPAR(L)=.TRUE.
            NRUPPIP(L)=0
            RUPPIP(L)=0
            RUPPIP2=0
        ELSE
           PIINTER(L,1)=1.0
        ENDIF
      ENDIF
    ENDIF
   21961 CONTINUE
    ENDIF
 IF(PWALL2.AND.PIFAIL.AND.(NRUPPIP(L).EQ.0))THEN
    IF(RUPPIP(L).LE.RUPPIP2.AND.(RUPPIP2.NE.0))THEN
           RUPPIP(L)=RUPPIP2
    ENDIF
   ELSE
    RUPPIP(L)=0
    RUPPIP2=0
 ENDIF
 ENDIF
    IF(AGPUMP)THEN
       PMPDRAN(2)=FNB(PMPDRAN(1))
       IF(PMPDRAN(2).EQ.1)THEN
          CALL FTIME(DRANPMP(L))
       ENDIF
    ENDIF
  501 CONTINUE
 IF((FILLING.EQ.1).OR.PORTFP.OR.PORTDP.OR.(DISCHRG.EQ.1))THEN
       PORTHOS(2)=FNB(PORTHOS(1))
       IF(PORTHOS(2).EQ.1)THEN
          CALL FTIME(HOSPORT)
       ENDIF
    ENDIF
 ENDIF
*
*  CALL ROUTINE THAT CHECKS FOR CORROSION LEAKS.
 CALL INADSTR(ANCIL,YR)
 RETURN
 END
 SUBROUTINE DEFICNT(LOC,YR,COMP)
*   THIS ROUTINE SAMPLES FOR ANY INSTALLATION DEFICEINCIES.
 COMMON/PIPELK/INTLK(5),PIPAGE(5),NUMLK(5),PRAN(5)
 INTEGER INTLK,NUMLK,PIPAGE
```

```
15370 REAL PRAN
15375 COMMON/THICKNS/PIPEI(5),PUMPI(5),GASKI(5)
15380 COMMON/EXTHICK/PIPEE(5),PUMPE(5),GASKE(5),PIPE2E(5),PIPE2I(5)
15385 REAL PIPEI,PUMPI,GASKI,PDIAM
15390 REAL PIPEE,PUMPE,GASKE,PIPE2E,PIPE2I
15395 COMMON/PIFRP/PFRP
15400 LOGICAL PFRP
15405 INTEGER LOC
15410 COMMON/IYRNO/IYRNUM
15415 COMMON/VAPPRB/VAPSENS,VSENSOR
15420 REAL VAPSENS,VSENSOR
15425*
15430 COMMON/PIPETIM/PIPDEF(5),WLDDEF(5),GSKDEF(5),PIPLK(5),
15435+GSKLK(5),RUPPIP(5)
15440 COMMON/TANKTIM/TNKDEF(3),TNKLK(3),RUPTNK(3)
15445
15450 INTEGER PIPDEF,WLDDEF,GSKDEF,PIPLK,GSKLK,RUPPIP
15455 INTEGER TNKDEF,TNKLK,RUPTNK
15460 COMMON/DEFPROB/LIFDEF(2,7),GSKINC(2)
15465 REAL LIFDEF,GSKINC
15470 COMMON/CONNECT/WELDFLG,GASKET
15475 LOGICAL WELDFLG,GASKET
15480 COMMON/FIDITYP/FILLING,DISCHRG
15485 INTEGER FILLING,DISCHRG
15490 COMMON/PUMPTYP/PORTFP,PORTDP
15495 LOGICAL PORTFP,PORTDP
15500 INTEGER COMP
15505 COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
15510 LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
15515 INTEGER FALNUM,FALNUM1,FALNUM3,FALNUM4,FALNUM7
15520 COMMON/FALNUM/FALNUM,FALNUM1(100),FALNUM2(100),FALNUM3(100),
15525+  FALNUM4(100),FALNUM5(100),FALNUM7(100)
15530 COMMON/FALNUM6/FALNUM6(100)
15535 CHARACTER FALNUM6*2
15540 REAL FALNUM2,FALNUM5
15545 COMMON/ITHICK/IPIPE(5),IPUMP(5),ITANK(3),IGASK(5),ITANK2(3)
15550 INTEGER IYRNUM,YR
15555 REAL IPIPE,IPUMP,ITANK,IGASK,ITANK2
15560 COMMON/EXTHI/TANKE(3),TANK2E(3)
15565 REAL TANKE,TANK2E
15570 COMMON/THICK/TANKI(3),TANK2I(3)
15575 REAL TANKI,TANK2I
15580 COMMON/ALARM/INTERST(5,2),INTER,PIINTER(5,2),PINTER
15585 REAL INTERST,INTER,PIINTER,PINTER
15590 COMMON/WALL/TK2WALL,PI2WALL
15595 LOGICAL TK2WALL,PI2WALL
15600 COMMON/MONIT/MONMETH(7),PIPMON
15605 LOGICAL MONMETH,PIPMON
15610 COMMON/COUNT/NPIPDEF(5),NWLDDEF(5),NGSKDEF(5),NPIPLK(5),NGSKLK(5),
15615+NRUPPIP(5),NPMPLK(5),NRUPWLD(5),NTNKLK(3),NTNKDEF(3),NRUPTNK(3)
15620 REAL NPIPDEF,NWLDDEF,NGSKDEF,NPIPLK,NGSKLK,NRUPPIP,NPMPLK,NRUPWLD,
15625+     NTNKLK,NTNKDEF,NRUPTNK
15630 LOGICAL PIREPAR,TKREPAR,PMREPAR
15635 COMMON/PITRE/PIREPAR(5),TKREPAR(3),PMREPAR(5)
15640 INTEGER TNKDEF2,PIPDEF2
15645 LOGICAL WALL2,TKFAIL
15650 LOGICAL PWALL2,PIFAIL
```

```
15655 IF(COMP.EQ.1)THEN
15660 PIPDEF(LOC)=0
15665 PIPDEF2=0
15670  IF(.NOT.PI2WALL)THEN
15675  IF(.NOT.((PORTDP.AND.(LOC.EQ.2)).OR.PORTFP))THEN
15680*    PIPE
15685     IF(.NOT.PFRP)THEN
15690      LIFDEF(2,5)=FNB(LIFDEF(1,5))
15695     ELSE
15700     LIFDEF(2,5)=FNB(LIFDEF(1,5)*2.)
15705     ENDIF
15710      IF(LIFDEF(2,5).EQ.1)THEN
15715           LIFDEF(2,3)=FNB(LIFDEF(1,3))
15720           IF(LIFDEF(2,3).EQ.1)THEN
15725              CALL REPLAC(1,LOC)
15730           ELSE
15735         CALL FTIME(PIPDEF(LOC))
15740           ENDIF
15745      ENDIF
15750  ENDIF
15755  ENDIF
15760     IF(PI2WALL)THEN
15765    IF(PFRP)THEN
15770     LIFDEF(2,5)=FNB(LIFDEF(1,5)*2.)
15775    ELSE
15780      LIFDEF(2,5)=FNB(LIFDEF(1,5))
15785     ENDIF
15790      IF(LIFDEF(2,5).EQ.1)THEN
15795         CALL FTIME(PIPDEF(LOC))
15800 PIFAIL=.TRUE.
15805     IF(NPIPDEF(LOC).EQ.0)THEN
15810*  INTERSTITIAL MONITORING
15815        IF(MONMETH(7))  THEN
15820          PIINTER(LOC,2)=FNB(PIINTER(LOC,1))
15825          IF(PIINTER(LOC,2).EQ.0)  THEN
15830             CALL REPLAC(1,LOC)
15835             FALNUM=FALNUM+1
15840             FALNUM1(FALNUM)=1010+LOC
15845              FALNUM7(FALNUM)=(YR-1)*12+PIPDEF(LOC)
15850             FALNUM2(FALNUM)=1.
15855             FALNUM3(FALNUM)=((YR-1)*12)+PIPDEF(LOC)
15860             FALNUM4(FALNUM)=2
15865             FALNUM6(FALNUM)='IS'
15870             PIPEI(LOC)=IPIPE(LOC)
15875             PIPEE(LOC)=IPIPE(LOC)
15880             PIPE2I(LOC)=IPIPE(LOC)
15885             PIPE2E(LOC)=IPIPE(LOC)
15890        INTLK(LOC)=0
15895        PIPAGE(LOC)=0
15900        NUMLK(LOC)=0
15905        PRAN(LOC)=FNU(0.,2.)
15910             PWALL2=.FALSE.
15915             PIFAIL=.FALSE.
15920             PIREPAR(LOC)=.TRUE.
15925             NPIPDEF(LOC)=0
15930             PIPDEF(LOC)=0
15935             PIPDEF2=0
```

```
15940        ELSE
15945           PIINTER(LOC,1)=1.0
15950        ENDIF
15955      ENDIF
15960    ENDIF
15965    ENDIF
15970   IF(PFRP)THEN
15975    LIFDEF(2,5)=FNB(LIFDEF(1,5)*2.)
15980   ELSE
15985     LIFDEF(2,5)=FNB(LIFDEF(1,5))
15990    ENDIF
15995     IF(LIFDEF(2,5).EQ.1)THEN
16000          LIFDEF(2,3)=FNB(LIFDEF(1,3))
16005          IF(LIFDEF(2,3).EQ.1)THEN
16010             CALL REPLAC(1,LOC)
16015          PIFAIL=.FALSE.
16020          PWALL2=.FALSE.
16025          ELSE
16030       PWALL2=.TRUE.
16035       CALL FTIME(PIPDEF2)
16040    IF(NPIPDEF(LOC).EQ.0)THEN
16045*  INTERSTITIAL MONITORING
16050       IF(MONMETH(7)) THEN
16055         PIINTER(LOC,2)=FNB(PIINTER(LOC,1))
16060         IF(PIINTER(LOC,2).EQ.0) THEN
16065            CALL REPLAC(1,LOC)
16070            FALNUM=FALNUM+1
16075            FALNUM1(FALNUM)=1010+LOC
16080            FALNUM7(FALNUM)=(YR-1)*12+PIPDEF2
16085            FALNUM2(FALNUM)=1.
16090            FALNUM3(FALNUM)=((YR-1)*12)+PIPDEF2
16095            FALNUM4(FALNUM)=2
16100            FALNUM6(FALNUM)='IS'
16105            PIPEI(LOC)=IPIPE(LOC)
16110            PIPEE(LOC)=IPIPE(LOC)
16115            PIPE2I(LOC)=IPIPE(LOC)
16120            PIPE2E(LOC)=IPIPE(LOC)
16125       INTLK(LOC)=0
16130       PIPAGE(LOC)=0
16135       NUMLK(LOC)=0
16140       PRAN(LOC)=FNU(0.,2.)
16145            PWALL2=.FALSE.
16150            PIFAIL=.FALSE.
16155            PIREPAR(LOC)=.TRUE.
16160            NPIPDEF(LOC)=0
16165            PIPDEF(LOC)=0
16170            PIPDEF2=0
16175        ELSE
16180           PIINTER(LOC,1)=1.0
16185        ENDIF
16190      ENDIF
16195    ENDIF
16200    ENDIF
16205 ENDIF
16210 IF(PWALL2.AND.PIFAIL.AND.(NPIPDEF(LOC).EQ.0))THEN
16215    IF(PIPDEF(LOC).LE.PIPDEF2.AND.(PIPDEF2.NE.0))THEN
16220           PIPDEF(LOC)=PIPDEF2
```

```
   ENDIF
  ELSE
      PIPDEF (LOC) =0
ENDIF
         ENDIF
ENDIF
IF (COMP.EQ.4) THEN
    IF (WELDFLG) THEN
    LIFDEF (2,5) =FNB (LIFDEF (1,5) *2.)
    IF (LIFDEF (2,5) .EQ.1) THEN
         LIFDEF (2,3) =FNB (LIFDEF (1,3))
         IF (LIFDEF (2,3) .EQ.1) THEN
         ELSE
       CALL  FTIME (WLDDEF (LOC))
         ENDIF
    ENDIF
  ENDIF
ENDIF
IF (COMP.EQ.5) THEN
  IF (GASKET) THEN
    LIFDEF (2,5) =FNB (LIFDEF (1,5) *1.5)
    IF (LIFDEF (2,5) .EQ.1) THEN
         LIFDEF (2,3) =FNB (LIFDEF (1,3))
         IF (LIFDEF (2,3) .EQ.1) THEN
         ELSE
       CALL  FTIME (GSKDEF (LOC))
         ENDIF
    ENDIF
 ENDIF
ENDIF
IF (COMP.EQ.3) THEN
*  TANK
TNKDEF (LOC) =0
TNKDEF2=0
   IF (.NOT.TK2WALL) THEN
  IF (FRP) THEN
   LIFDEF (2,5) =FNB (LIFDEF (1,5) *4.)
  ELSE
    LIFDEF (2,5) =FNB (LIFDEF (1,5) *3.)
   ENDIF
    IF (LIFDEF (2,5) .EQ.1) THEN
         LIFDEF (2,3) =FNB (LIFDEF (1,3))
         IF (LIFDEF (2,3) .EQ.1) THEN
            CALL  REPLAC (3,1)
VAPSENS=VSENSOR
         ELSE
       CALL  FTIME (TNKDEF (LOC))
         ENDIF
    ENDIF
   ENDIF
   IF (TK2WALL) THEN
  IF (FRP) THEN
   LIFDEF (2,5) =FNB (LIFDEF (1,5) *4.)
  ELSE
    LIFDEF (2,5) =FNB (LIFDEF (1,5) *3.)
   ENDIF
    IF (LIFDEF (2,5) .EQ.1) THEN
```

```
       CALL FTIME(TNKDEF(LOC))
TKFAIL=.TRUE.
   IF(NTNKDEF(LOC).EQ.0)THEN
*  INTERSTITIAL MONITORING
      IF(MONMETH(2))  THEN
        INTERST(LOC,2)=FNB(INTERST(LOC,1))
        IF(INTERST(LOC,2).EQ.0)  THEN
           CALL REPLAC(3,1)
VAPSENS=VSENSOR
           FALNUM=FALNUM+1
           FALNUM1(FALNUM)=1030+LOC
            FALNUM7(FALNUM)=(YR-1)*12+TNKDEF(LOC)
           FALNUM2(FALNUM)=1.
           FALNUM3(FALNUM)=((YR-1)*12)+TNKDEF(LOC)
           FALNUM4(FALNUM)=2
           FALNUM6(FALNUM)='IS'
           TANKI(LOC)=ITANK(LOC)
           TANKE(LOC)=ITANK(LOC)
           TANK2I(LOC)=ITANK(LOC)
           TANK2E(LOC)=ITANK(LOC)
           WALL2=.FALSE.
           TKFAIL=.FALSE.
           TKREPAR(LOC)=.TRUE.
           NTNKDEF(LOC)=0
           TNKDEF(LOC)=0
           TNKDEF2=0
       ELSE
          INTERST(LOC,1)=1.0
       ENDIF
     ENDIF
   ENDIF
   ENDIF
  IF(FRP)THEN
   LIFDEF(2,5)=FNB(LIFDEF(1,5)*4.)
  ELSE
    LIFDEF(2,5)=FNB(LIFDEF(1,5)*3.)
   ENDIF
    IF(LIFDEF(2,5).EQ.1)THEN
         LIFDEF(2,3)=FNB(LIFDEF(1,3))
         IF(LIFDEF(2,3).EQ.1)THEN
            CALL REPLAC(3,1)
VAPSENS=VSENSOR
         TKFAIL=.FALSE.
         WALL2=.FALSE.
         ELSE
      WALL2=.TRUE.
      CALL FTIME(TNKDEF2)
   IF(NTNKDEF(LOC).EQ.0)THEN
*  INTERSTITIAL MONITORING
      IF(MONMETH(2))  THEN
        INTERST(LOC,2)=FNB(INTERST(LOC,1))
        IF(INTERST(LOC,2).EQ.0)  THEN
           CALL REPLAC(3,1)
VAPSENS=VSENSOR
           FALNUM=FALNUM+1
           FALNUM1(FALNUM)=1030+LOC
           FALNUM7(FALNUM)=(YR-1)*12+TNKDEF2
```

```
16795           FALNUM2(FALNUM)=1.
16800           FALNUM3(FALNUM)=((YR-1)*12)+TNKDEF2
16805           FALNUM4(FALNUM)=2
16810           FALNUM6(FALNUM)='IS'
16815           TANKI(LOC)=ITANK(LOC)
16820           TANKE(LOC)=ITANK(LOC)
16825           TANK2I(LOC)=ITANK(LOC)
16830           TANK2E(LOC)=ITANK(LOC)
16835           WALL2=.FALSE.
16840           TKFAIL=.FALSE.
16845           TKREPAR(LOC)=.TRUE.
16850           NTNKDEF(LOC)=0
16855           TNKDEF(LOC)=0
16860           TNKDEF2=0
16865       ELSE
16870          INTERST(LOC,1)=1.0
16875       ENDIF
16880     ENDIF
16885   ENDIF
16890   ENDIF
16895 ENDIF
16900 IF(WALL2.AND.TKFAIL.AND.(NTNKDEF(LOC).EQ.0))THEN
16905   IF(TNKDEF(LOC).LE.TNKDEF2)THEN
16910          TNKDEF(LOC)=TNKDEF2
16915  ELSE
16920* VISUAL INSPECTION OF WALL2
16925      TNKDEF(LOC)=0
16930   ENDIF
16935 ENDIF
16940         ENDIF
16945    ENDIF
16950 RETURN
16955 END
16960 SUBROUTINE SPILLS
16965*  SAMPLES THE PROBABILITY OF A LOOSE HOSE CONNECTION.
16970 COMMON/FIDITYP/FILLING,DISCHRG
16975 INTEGER FILLING,DISCHRG
16980 COMMON/SPLPRB/LOOSCON(2)
16985 REAL LOOSCON
16990 LOGICAL LOOP
16995 INTEGER MON
17000 COMMON/SURFTIM/LOOSE,HOSPORT,PMPLK(5),RUPWLD(5),VENT
17005 INTEGER LOOSE,HOSPORT,PMPLK,RUPWLD,VENT
17010 IF((DISCHRG.EQ.1).OR.(FILLING.EQ.1))THEN
17015   LOOSCON(2)=FNB(LOOSCON(1))
17020   IF(LOOSCON(2).EQ.1)THEN
17025      CALL FTIME(LOOSE)
17030   ENDIF
17035 ENDIF
17040 RETURN
17045 END
17050 SUBROUTINE TNKCONT(L)
17055*   SAMPLES THE PROBABILITY OF TANK SECONDARY CONTAINMENT
17060* FAILURES (EXCLUDING DOUBLE-WALLED STEEL TANKS).
17065 INTEGER L
17070 COMMON/DEFSEC/SECDEF(2)
17075 REAL SECDEF
```

```
17080 COMMON/LIN/LINER
17085 LOGICAL LINER
17090 COMMON/TIME/APADTIM(3),CPADTIM(3),VLTTIM(3),CBRMTIM(3),ABRMTIM(3)
17095 REAL APADTIM,CPADTIM,VLTTIM,CBRMTIM,ABRMTIM
17100 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
17105 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
17110 COMMON/DEFPROB/LIFDEF(2,7),GSKINC(2)
17115 REAL LIFDEF,GSKINC
17120 COMMON/IYRNO/IYRNUM
17125*
17130 COMMON/TKCONT/CONCPAD,ASPHPAD
17135 COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
17140 COMMON/CONT/UGCONT(3),AGCONT(3),PIPCONT(5),NUGCONT(3),NAGCONT(3)
17145+,NPICONT(5)
17150 COMMON/LINE/LINETIM(3)
17155 LOGICAL CONCPAD,ASPHPAD
17160 LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
17165 INTEGER UGCONT,AGCONT,PIPCONT,NUGCONT,NAGCONT,NPICONT
17170 REAL LINETIM
17175 REAL SETTLE
17180 INTEGER IYRNUM
17185 IF(ULVAULT)THEN
17190 IF(IYRNUM.EQ.1)THEN
17195     SECDEF(2)=FNB(SECDEF(1))
17200     IF(SECDEF(2).EQ.1)THEN
17205           CALL FTIME(UGCONT(L))
17210     ENDIF
17215     IF(VAULT.OR.CONCPAD.OR.ASPHPAD)THEN
17220*       SETTLING FAILURES
17225     LIFDEF(2,6)=FNB(LIFDEF(1,6))
17230     LIFDEF(2,7)=FNB(LIFDEF(1,7))
17235     SETTLE=1-(1-LIFDEF(2,6))*(1-LIFDEF(2,7))
17240     IF(SETTLE.EQ.1)THEN
17245           CALL FTIME(UGCONT(L))
17250     ENDIF
17255     ENDIF
17260 ENDIF
17265     IF(VLTTIM(L).LE.IYRNUM)THEN
17270        CALL FTIME(UGCONT(L))
17275     ENDIF
17280 ENDIF
17285 IF(LVAULT)THEN
17290 IF(IYRNUM.EQ.1)THEN
17295     SECDEF(2)=FNB(SECDEF(1))
17300     IF(SECDEF(2).EQ.1)THEN
17305           VLTTIM(L)=100.
17310     ENDIF
17315     IF(VAULT.OR.CONCPAD.OR.ASPHPAD)THEN
17320*       SETTLING FAILURES
17325     LIFDEF(2,6)=FNB(LIFDEF(1,6))
17330     LIFDEF(2,7)=FNB(LIFDEF(1,7))
17335     SETTLE=1-(1-LIFDEF(2,6))*(1-LIFDEF(2,7))
17340     IF(SETTLE.EQ.1)THEN
17345           VLTTIM(L)=100.
17350     ENDIF
17355     ENDIF
17360 ENDIF
```

```
17365    IF(LINETIM(L).LE.IYRNUM)THEN
17370       IF(VLTTIM(L).LE.IYRNUM)THEN
17375          CALL FTIME(UGCONT(L))
17380       ENDIF
17385    ENDIF
17390 ENDIF
17395*AG CONTAINMENT FAILS
17400 IF(CONCPAD)THEN
17405 IF(IYRNUM.EQ.1)THEN
17410    SECDEF(2)=FNB(SECDEF(1))
17415    IF(SECDEF(2).EQ.1)THEN
17420          CPADTIM(L)=100.
17425    ENDIF
17430    IF(VAULT.OR.CONCPAD.OR.ASPHPAD)THEN
17435*      SETTLING FAILURES
17440    LIFDEF(2,6)=FNB(LIFDEF(1,6))
17445    LIFDEF(2,7)=FNB(LIFDEF(1,7))
17450    SETTLE=1-(1-LIFDEF(2,6))*(1-LIFDEF(2,7))
17455    IF(SETTLE.EQ.1)THEN
17460          CPADTIM(L)=100.
17465    ENDIF
17470    ENDIF
17475 ENDIF
17480 IF(LINER)THEN
17485    IF(LINETIM(L).LE.IYRNUM)THEN
17490  IF((CPADTIM(L).LE.IYRNUM).OR.(CBRMTIM(L).LE.IYRNUM))THEN
17495       CALL FTIME(AGCONT(L))
17500    ENDIF
17505     ENDIF
17510 ELSE
17515    IF((CPADTIM(L).LE.IYRNUM).OR.(CBRMTIM(L).LE.IYRNUM))THEN
17520       CALL FTIME(AGCONT(L))
17525    ENDIF
17530 ENDIF
17535   ELSEIF(ASPHPAD)THEN
17540 IF(IYRNUM.EQ.1)THEN
17545    SECDEF(2)=FNB(SECDEF(1))
17550    IF(SECDEF(2).EQ.1)THEN
17555          APADTIM(L)=100.
17560    ENDIF
17565    IF(VAULT.OR.CONCPAD.OR.ASPHPAD)THEN
17570*      SETTLING FAILURES
17575    LIFDEF(2,6)=FNB(LIFDEF(1,6))
17580    LIFDEF(2,7)=FNB(LIFDEF(1,7))
17585    SETTLE=1-(1-LIFDEF(2,6))*(1-LIFDEF(2,7))
17590    IF(SETTLE.EQ.1)THEN
17595          APADTIM(L)=100.
17600    ENDIF
17605    ENDIF
17610 ENDIF
17615 IF(LINER)THEN
17620    IF(LINETIM(L).LE.IYRNUM)THEN
17625  IF((APADTIM(L).LE.IYRNUM).OR.(ABRMTIM(L).LE.IYRNUM))THEN
17630       CALL FTIME(AGCONT(L))
17635    ENDIF
17640    ENDIF
17645 ELSE
```

```
17650     IF((APADTIM(L).LE.IYRNUM).OR.(ABRMTIM(L).LE.IYRNUM))THEN
17655        CALL FTIME(AGCONT(L))
17660     ENDIF
17665 ENDIF
17670   ELSE
17675*    NO PAD OR CURB
17680     IF(.NOT.LINER)AGCONT(L)=1
17685 ENDIF
17690 IF(LINER.AND.(.NOT.(VAULT.OR.CONCPAD.OR.ASPHPAD)))THEN
17695     IF(LINETIM(L).LE.IYRNUM)THEN
17700        IF(UGTANK.OR.IGTANK)THEN
17705           CALL FTIME(UGCONT(L))
17710        ELSE
17715           CALL FTIME(AGCONT(L))
17720        ENDIF
17725     ENDIF
17730 ENDIF
17735 RETURN
17740 END
17745 SUBROUTINE INADSTR(ANCIL,YR)
17750*    CHECKS FOR FAILURES DUE TO CORROSION.
17755 LOGICAL PWALL2,PIFAIL
17760 COMMON/PMATL/PCSTEEL,PSSTEEL
17765 LOGICAL PCSTEEL,PSSTEEL
17770 COMMON/CTFL/CTFLAG
17775 LOGICAL CTFLAG
17780 COMMON/CATHOD/CATFAIL
17785 LOGICAL CATFAIL
17790 COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
17795 LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
17800 COMMON/COATIM/ICOATIM(3,5),ECOATIM(3,5)
17805 REAL ICOATIM,ECOATIM
17810 COMMON/COATS/COATING(4,3,5)
17815 LOGICAL COATING
17820 COMMON/LKLEN/PILKWID(5),PILKLEN(5)
17825 REAL PILKWID,PILKLEN
17830 COMMON/CWID/PIDFWID(5),RPPIWID(5),TKDFWID(3),RPTKWID(3),WLDFWID
17835+(5),GKDFWID(5),RPWLWID(5)
17840 REAL PIDFWID,RPPIWID,TKDFWID,RPTKWID,WLDFWID,
17845+GKDFWID,RPWLWID
17850 COMMON/CLEN/PIDFLEN(5),RPPILEN(5),TKDFLEN(3),RPTKLEN(3),WLDFLEN
17855+(3),GKDFLEN(5),RPWLLEN(5)
17860 REAL PIDFLEN,RPPILEN,TKDFLEN,RPTKLEN,WLDFLEN,
17865+GKDFLEN,RPWLLEN
17870 REAL PIPLEN
17875 COMMON/PIPEDM/PIPLEN(5)
17880 COMMON/LENMIN/CLENMIN(5),CWIDMIN(5),CDIMMIN(5)
17885 REAL CLENMIN,CWIDMIN,CDIMMIN
17890 COMMON/RUPLEN/CLENGTH(5),CWIDTH(5),CDIAM(5)
17895 REAL CLENGTH,CWIDTH,CDIAM
17900 COMMON/COUNT/NPIPDEF(5),NWLDDEF(5),NGSKDEF(5),NPIPLK(5),NGSKLK(5),
17905+NRUPPIP(5),NPMPLK(5),NRUPWLD(5),NTNKLK(3),NTNKDEF(3),NRUPTNK(3)
17910 REAL NPIPDEF,NWLDDEF,NGSKDEF,NPIPLK,NGSKLK,NRUPPIP,NPMPLK,NRUPWLD,
17915+      NTNKLK,NTNKDEF,NRUPTNK
17920       COMMON/AX/IY
17925 REAL TEMPDIA,TAREA
17930 LOGICAL LKFLAG
```

```
17935 COMMON/PIPELK/INTLK(5),PIPAGE(5),NUMLK(5),PRAN(5)
17940 INTEGER INTLK,NUMLK,PIPAGE
17945 REAL PRAN
17950 COMMON/CDIAM/PIDFDIA(5),PILKDIA(5),PMLKDIA(5),GKLKDIA(5),TKLKDIA
17955+(3)
17960 REAL PIDFDIA,PILKDIA,PMLKDIA,GKLKDIA,TKLKDIA
17965 COMMON/AREAS2/PIPESA(5)
17970 REAL PIPESA
17975 COMMON/MODE/CDIMMOD(5)
17980 REAL CDIMMOD
17985 COMMON/LOOPCT/NPI,NTK
17990 INTEGER NPI,NTK
17995 COMMON/IYRNO/IYRNUM
18000 COMMON/VAPPRB/VAPSENS,VSENSOR
18005 REAL VAPSENS,VSENSOR
18010 INTEGER FALNUM,FALNUM1,FALNUM3,FALNUM4,FALNUM7
18015 COMMON/FALNUM/FALNUM,FALNUM1(100),FALNUM2(100),FALNUM3(100),
18020+  FALNUM4(100),FALNUM5(100),FALNUM7(100)
18025 COMMON/FALNUM6/FALNUM6(100)
18030 CHARACTER FALNUM6*2
18035 REAL FALNUM2,FALNUM5
18040
18045 COMMON/PIPETIM/PIPDEF(5),WLDDEF(5),GSKDEF(5),PIPLK(5),
18050+GSKLK(5),RUPPIP(5)
18055 COMMON/TANKTIM/TNKDEF(3),TNKLK(3),RUPTNK(3)
18060 COMMON/SURFTIM/LOOSE,HOSPORT,PMPLK(5),RUPWLD(5),VENT
18065
18070 INTEGER PIPDEF,WLDDEF,GSKDEF,PIPLK,GSKLK,RUPPIP
18075 INTEGER TNKDEF,TNKLK,RUPTNK,TNK2
18080 INTEGER PIP2
18085 INTEGER LOOSE,HOSPORT,PMPLK,RUPWLD,VENT
18090 LOGICAL ANCIL
18095*RELEASE DUE TO INADEQUATE COMPONENT STRENGTH
18100 COMMON/PRESS/PRESS(5,5)
18105 COMMON/STRESS/STRESS(5),CORTHDS(2)
18110 COMMON/THICKNS/PIPEI(5),PUMPI(5),GASKI(5)
18115 COMMON/ITHICK/IPIPE(5),IPUMP(5),ITANK(3),IGASK(5),ITANK2(3)
18120 COMMON/DIAM/PDIAM(5)
18125 COMMON/MATL/TNKMATL,PIPMATL
18130 INTEGER IYRNUM,YR
18135 REAL IPIPE,IPUMP,ITANK,IGASK,ITANK2
18140 COMMON/EXTHICK/PIPEE(5),PUMPE(5),GASKE(5),PIPE2E(5),PIPE2I(5)
18145 COMMON/EXTHI/TANKE(3),TANK2E(3)
18150 REAL TANKE,TANK2E
18155 REAL PIPEE,PUMPE,GASKE,PIPE2E,PIPE2I
18160 REAL PRESS,PIPEI,PUMPI,GASKI,PDIAM
18165 COMMON/THICK/TANKI(3),TANK2I(3)
18170 REAL TANKI,TANK2I
18175 COMMON/CORE/PCORE(5),GCORE(5),PMCORE(5),TCORE(3),TCORE2(3)
18180 COMMON/CORE1/PCORE2(5),PIEXT2(5),PIEXLO2(5)
18185 REAL PCORE2,PIEXT2,PIEXLO2
18190 REAL PCORE,GCORE,PMCORE,TCORE,TCORE2
18195 REAL STRESS,CORTHDS
18200 INTEGER TNKMATL,PIPMATL
18205 LOGICAL TKFAIL
18210 COMMON/ALARM/INTERST(5,2),INTER,PIINTER(5,2),PINTER
18215 REAL INTERST,INTER,PIINTER,PINTER
```

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18220 COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
18225 LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
18230 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
18235 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPUMP,AGPIPE
18240 COMMON/WALL/TK2WALL,PI2WALL
18245 LOGICAL TK2WALL,PI2WALL,WALL2
18250 COMMON/MONIT/MONMETH(7),PIPMON
18255 LOGICAL MONMETH,PIPMON
18260 COMMON/ECORE/PIEXT(5),TKEXT(3),PMEXT(5),TKEXT2(3)
18265 REAL PIEXT,TKEXT,PMEXT,TKEXT2
18270 COMMON/ILOCAL/PILOCAL(5),PMLOCAL(5),TKLOCAL(3),TKLOCA2(3)
18275 REAL PILOCAL,PMLOCAL,TKLOCAL,TKLOCA2
18280 COMMON/ELOCAL/PIEXLOC(5),TKEXLOC(3),TKEXLO2(3)
18285 REAL PIEXLO,TKEXLO,TKEXLO2
18290 INTEGER PIP,PMP,GSK
18295 COMMON/VENT/VCORE,VENTI,VENTE,IVENT,VLOCAL,VNTLOC,VEXT,
18300+VEXTLOC
18305 REAL VNTLOC
18310 REAL VCORE,VENTI,VENTE,IVENT,VLOCAL,VEXT,VEXTLOC
18315 LOGICAL PIREPAR,TKREPAR,PMREPAR
18320 COMMON/PITRE/PIREPAR(5),TKREPAR(3),PMREPAR(5)
18325*COMPONENTS
18330* 1=PIPE
18335* 2=PUMP
18340* 3=TANK
18345* 4=WELDED FLANGE
18350* 5=GASKET
18355*MATERIALS
18360* 1=CARBON STEEL
18365* 2=STAINLESS STEEL
18370* 3=FRP
18375* 4=CONCRETE
18380* 5=GASKET MATERIAL
18385*FILL-DISCHARGE STEP
18390* 1=FILLING STEP
18395* 5=DISCHARGE STEP
18400 IF(ANCIL)THEN
18405     DO 10 I=1,NPI
18410     PIFAIL=.FALSE.
18415     PWALL2=.FALSE.
18420     PIPLK(I)=0
18425     PIP2=0
18430 IF(I.EQ.1)THEN
18435 CALL THLOSS(VENTI,VENTE,VCORE,VEXT,VLOCAL,VEXTLOC,1,1)
18440 IF((VENT.LE.0).OR.(VENTE.LE.0.))THEN
18445     CALL FTIME(VENT)
18450 ENDIF
18455 ENDIF
18460 IF(AGPIPE)THEN
18465 CALL THLOSS(PIPEI(I),PIPEE(I),PCORE(I),PIEXT(I),PILOCAL(I),
18470+PIEXLOC(I),1,I)
18475 ELSE
18480 CALL THLOSS(PIPEI(I),PIPEE(I),PCORE(I),0.,PILOCAL(I),0.,1,I)
18485 ENDIF
18490*PRESSUR=PRESS(I,1)
18495*BURSTP=(2*STRNGTH(PIPEI(I),1,I,PIPMATL)*PIPEI(I))/PDIAM(I)
18500 IF(PIPEI(I).LE.0.)THEN
```

```
     CALL FTIME(PIPLK(I))
     PIFAIL=.TRUE.
     IF((INTLK(I).EQ.0).AND.UGPIPE)THEN
         TEMPDIA=FNBE(CDIMMOD(1),CDIMMIN(1),CDIAM(1))
         TAREA=(((TEMPDIA/2.)**2)+((PILKDIA(I)/2.)**2))*3.1416
         PILKDIA(I)=SQRT(TAREA/3.1416)*2
         INTLK(I)=1
     ENDIF
 ENDIF
 IF((PICATH.OR.CATSTEL).AND.(.NOT.CATFAIL))GO TO 26249
 IF(.NOT.COATING(4,1,1))THEN
     IF(ECOATIM(1,I).LE.IYRNUM)THEN
         CTFLAG=.TRUE.
        ELSE
         GO TO 26249
     ENDIF
 ENDIF
 IF(.NOT.PI2WALL)THEN
 IF(UGPIPE)THEN
 PIPAGE(I)=PIPAGE(I)+1
 LKFLAG=.FALSE.
 IF(PIPEE(I).GT.0)THEN
 IF(PSSTEEL)THEN
     PAGE=PIPAGE(I)/4.
 ELSE
     PAGE=PIPAGE(I)
 ENDIF
 CALL LKPIPE(PAGE,PIPESA(I),PIPEE(I),NUMLK(I),PRAN(I),LKFLAG,
+CTFLAG)
 IF(LKFLAG)THEN
     NUMLK(I)=NUMLK(I)+1
     TEMPDIA=FNBE(CDIMMOD(1),CDIMMIN(1),CDIAM(1))
     TAREA=(((TEMPDIA/2.)**2)+((PILKDIA(I)/2.)))*3.1416
     PILKDIA(I)=SQRT(TAREA/3.1416)*2
     PRAN(I)=FNU(0.,2.)
     LKFLAG=.FALSE.
     CALL FTIME(PIP)
     IF(PIP.LT.PIPLK(I).OR.(PIPLK(I).EQ.0))PIPLK(I)=PIP
 ENDIF
 ELSE
     IF(NPIPLK(I).EQ.0)THEN
     PILKLEN(I)=FNU(CLENMIN(1),CLENGTH(1))
     PILKWID(I)=FNU(CWIDMIN(1),CWIDTH(1))
     ELSE
     PILKLEN(I)=2*PILKLEN(I)
     IF(PILKLEN(I).GT.PIPLEN(I))PILKLEN(I)=PIPLEN(I)
     PILKWID(I)=2*PILKWID(I)
     IF(PILKWID(I).GT.3.)PILKWID(I)=3.0
     ENDIF
     CALL FTIME(PIP)
     IF(PIP.LT.PIPLK(I).OR.(PIPLK(I).EQ.0))PIPLK(I)=PIP
 ENDIF
 ELSE
*BURSTP=(2*STRNGTH(PIPEE(I),1,I,PIPMATL)*PIPEE(I))/PDIAM(I)
 IF(PIPEE(I).LE.0.)THEN
     CALL FTIME(PIP)
     IF(PIP.LT.PIPLK(I).OR.(PIPLK(I).EQ.0))PIPLK(I)=PIP
```

```
18790 ENDIF
18795 ENDIF
18800 ENDIF
18805 26249 CONTINUE
18810 IF(PI2WALL)THEN
18815    IF(PIFAIL.AND.NPIPLK(I).EQ.0)THEN
18820*     INTERSTITAL MONITORING
18825       IF(MONMETH(7)) THEN
18830         PIINTER(I,2)=FNB(PIINTER(I,1))
18835         IF(PIINTER(I,2).EQ.0) THEN
18840            CALL REPLAC(1,I)
18845            FALNUM=FALNUM+1
18850            FALNUM1(FALNUM)=3010+I
18855            FALNUM7(FALNUM)=(YR-1)*12+PIPLK(I)
18860            FALNUM2(FALNUM)=1.
18865            FALNUM3(FALNUM)=((YR-1)*12)+PIPLK(I)
18870            FALNUM4(FALNUM)=2
18875            FALNUM6(FALNUM)='IS'
18880            PIPEI(I)=IPIPE(I)
18885            PIPEE(I)=IPIPE(I)
18890            PIPE2I(I)=IPIPE(I)
18895            PIPE2E(I)=IPIPE(I)
18900            PWALL2=.FALSE.
18905            PIFAIL=.FALSE.
18910            PIREPAR(I)=.TRUE.
18915            NPIPLK(I)=0
18920            PIPLK(I)=0
18925            PIP2=0
18930          PIPAGE(I)=0
18935          NUMLK(I)=0
18940          INTLK(I)=0
18945          PRAN(I)=FNU(0.,2.)
18950        ELSE
18955           PIINTER(I,1)=1.0
18960        ENDIF
18965      ENDIF
18970    ENDIF
18975 IF((PICATH.OR.CATSTEL).AND.(.NOT.CATFAIL))GO TO 26248
18980 IF(.NOT.COATING(4,1,I))THEN
18985    IF(ECOATIM(1,I).LE.IYRNUM)THEN
18990       CTFLAG=.TRUE.
18995    ELSE
19000       GO TO 26248
19005    ENDIF
19010 ENDIF
19015 IF(UGPIPE)THEN
19020 PIPAGE(I)=PIPAGE(I)+1
19025 LKFLAG=.FALSE.
19030 IF(PIPE2E(I).GT.0)THEN
19035    IF(PSSTEEL)THEN
19040       PAGE=PIPAGE(I)/4.
19045    ELSE
19050       PAGE=PIPAGE(I)
19055    ENDIF
19060 CALL LKPIPE(PAGE,PIPESA(I),PIPE2E(I),NUMLK(I),PRAN(I),LKFLAG,
19065+CTFLAG)
19070 IF(NUMLK(I).GT.0)PWALL2=.TRUE.
```

```
IF (LKFLAG) THEN
   NUMLK(I)=NUMLK(I)+1
   PWALL2=.TRUE.
   TEMPDIA=FNBE(CDIMMOD(I),CDIMMIN(I),CDIAM(I))
   TAREA=(((TEMPDIA/2.)**2)+((PILKDIA(I)/2.)))*3.1416
   PILKDIA(I)=SQRT(TAREA/3.1416)*2
   PRAN(I)=FNU(0.,2.)
   LKFLAG=.FALSE.
   CALL FTIME(PIP2)
   IF (NPIPLK(I).EQ.0) THEN
*     INTERSTITAL MONITORING
      IF (MONMETH(7)) THEN
        PIINTER(I,2)=FNB(PIINTER(I,1))
        IF (PIINTER(I,2).EQ.0) THEN
           CALL REPLAC(1,I)
           FALNUM=FALNUM+1
           FALNUM1(FALNUM)=3010+I
           FALNUM7(FALNUM)=(YR-1)*12+PIP2
           FALNUM2(FALNUM)=1.
           FALNUM3(FALNUM)=((YR-1)*12)+PIP2
           FALNUM4(FALNUM)=2
           FALNUM6(FALNUM)='IS'
           PIPEI(I)=IPIPE(I)
           PIPEE(I)=IPIPE(I)
           PIPE2I(I)=IPIPE(I)
           PIPE2E(I)=IPIPE(I)
           PWALL2=.FALSE.
           PIFAIL=.FALSE.
           PIREPAR(I)=.TRUE.
           NPIPLK(I)=0
           PIPLK(I)=0
           PIP2=0
         INTLK(I)=0
         PIPAGE(I)=0
         NUMLK(I)=0
         PRAN(I)=FNU(0.,2.)
       ELSE
          PIINTER(I,1)=1.0
       ENDIF
     ENDIF
   ENDIF
ENDIF
ELSE
PWALL2=.TRUE.
   IF (NPIPLK(I).EQ.0) THEN
   PILKLEN(I)=FNU(CLENMIN(I),CLENGTH(I))
   PILKWID(I)=FNU(CWIDMIN(I),CWIDTH(I))
   ELSE
   PILKLEN(I)=2*PILKLEN(I)
   IF (PILKLEN(I).GT.PIPLEN(I)) PILKLEN(I)=PIPLEN(I)
   PILKWID(I)=2*PILKWID(I)
   IF (PILKWID(I).GT.3.) PILKWID(I)=3.0
   ENDIF
   CALL FTIME(PIP2)
ENDIF
ENDIF
IF (PWALL2.AND.PIFAIL.AND.(NPIPLK(I).EQ.0)) THEN
```

```
     IF((PIPLK(I).LE.PIP2).AND.(PIP2.NE.0))THEN
        PIPLK(I)=PIP2
      ENDIF
    ELSE
     PIPLK(I)=0
 ENDIF
 26248 CONTINUE
 ENDIF
 IF(AGPUMP)THEN
*PRESSUR=PRESS(I,2)
 CALL THLOSS(PUMPI(I),PUMPE(I),PMCORE(I),PMEXT(I),PMLOCAL
+(I),0.,2,I)
*     BURSTP=(2*STRNGTH(PUMPI(I),2,I,1)*PUMPI(I))/PDIAM(I)
 IF(PUMPI(I).LE.0)THEN
 CALL FTIME(PMPLK(I))
 ENDIF
*BURSTP=(2*STRNGTH(PUMPE(I),1,I,1)*PUMPE(I))/PDIAM(I)
 IF(PUMPE(I).LE.0)THEN
     CALL FTIME(PMP)
     IF(PMP.LT.PMPLK(I).OR.(PMPLK(I).EQ.0))PMPLK(I)=PMP
 ENDIF
 ENDIF
 GASKI(I)=GASKI(I)-GCORE(I)
 GASKE(I)=GASKE(I)-GCORE(I)
*     BURSTP=2*STRNGTH(GASKI(I),5,I,PIPMATL)*GASKI(I)/PDIAM(I)
 IF(GASKI(I).LE.0.)THEN
 CALL FTIME(GSKLK(I))
 ENDIF
*BURSTP=(2*STRNGTH(GASKE(I),1,I,PIPMATL)*GASKE(I))/PDIAM(I)
 IF(GASKE(I).LE.0.)THEN
     CALL FTIME(GSK)
     IF(GSK.LT.GSKLK(I).OR.(GSKLK(I).EQ.0))GSKLK(I)=GSK
 ENDIF
 10 CONTINUE
 ENDIF
 DO 101 I=1,NTK
 TKFAIL=.FALSE.
 WALL2=.FALSE.
 IF(.NOT.ANCIL)THEN
 IF(.NOT.TK2WALL)THEN
 CALL THLOSS(TANKI(I),TANKE(I),TCORE(I),TKEXT(I),TKLOCAL(I),
+TKEXLOC(I),3,I)
 IF((TANKI(I).LE.0.).OR.(TANKE(I).LE.0.))THEN
 CALL FTIME(TNKLK(I))
 TKFAIL=.TRUE.
 ENDIF
 ENDIF
 IF(TK2WALL)THEN
 CALL THLOSS(TANKI(I),TANKE(I),TCORE(I),0.,TKLOCAL(I),0.,3,I)
 IF((TANKI(I).LE.0).OR.(TANKE(I).LE.0.))THEN
 CALL FTIME(TNKLK(I))
 TKFAIL=.TRUE.
     IF(NTNKLK(I).EQ.0)THEN
*  INTERSTITIAL MONOTORING
        IF(MONMETH(2)) THEN
           INTERST(I,2)=FNB(INTERST(I,1))
           IF(INTERST(I,2).EQ.0) THEN
           CALL REPLAC(3,1)
VAPSENS=VSENSOR
           FALNUM=FALNUM+1
           FALNUM1(FALNUM)=3030+I
           FALNUM7(FALNUM)=(YR-1)*12+TNKLK(I)
           FALNUM2(FALNUM)=1.
           FALNUM3(FALNUM)=((YR-1)*12)+TNKLK(I)
           FALNUM4(FALNUM)=2
           FALNUM6(FALNUM)='IS'
           TANKI(I)=ITANK(I)
           TANKE(I)=ITANK(I)
           TANK2I(I)=ITANK(I)
           TANK2E(I)=ITANK(I)
           WALL2=.FALSE.
           TKFAIL=.FALSE.
           TKREPAR(I)=.TRUE.
           NTNKLK(I)=0
           TNKLK(I)=0
           TNK2=0
       ELSE
          INTERST(I,1)=1.0
       ENDIF
     ENDIF
   ENDIF
ENDIF
CALL THLOSS(TANK2I(I),TANK2E(I),0.,TKEXT2(I),0.,TKEXLO2,3,I)
   IF((TANK2I(I).LE.0.).OR.(TANK2E(I).LE.0.))THEN
     WALL2=.TRUE.
     CALL FTIME(TNK2)
   IF(NTNKLK(I).EQ.0)THEN
*  INTERSTITIAL MONOTORING
     IF(MONMETH(2)) THEN
        INTERST(I,2)=FNB(INTERST(I,1))
        IF(INTERST(I,2).EQ.0) THEN
           CALL REPLAC(3,1)
VAPSENS=VSENSOR
           FALNUM=FALNUM+1
           FALNUM1(FALNUM)=3030+I
           FALNUM7(FALNUM)=(YR-1)*12+TNK2
           FALNUM2(FALNUM)=1.
           FALNUM3(FALNUM)=((YR-1)*12)+TNK2
           FALNUM4(FALNUM)=2
           FALNUM6(FALNUM)='IS'
           TANKI(I)=ITANK(I)
           TANKE(I)=ITANK(I)
           TANK2I(I)=ITANK(I)
           TANK2E(I)=ITANK(I)
           WALL2=.FALSE.
           TKFAIL=.FALSE.
           TKREPAR(I)=.TRUE.
           NTNKLK(I)=0
           TNKLK(I)=0
           TNK2=0
       ELSE
          INTERST(I,1)=1.0
       ENDIF
     ENDIF
```

```
19930     ENDIF
19935     ENDIF
19940 IF(WALL2.AND.TKFAIL.AND.(NTNKLK(I).EQ.0))THEN
19945     IF(TNKLK(I).LE.TNK2)THEN
19950             TNKLK(I)=TNK2
19955   ELSE
19960* VISUAL INSPECTION OF WALL2
19965         TNKLK(I)=0
19970     ENDIF
19975 ENDIF
19980 ENDIF
19985 ENDIF
19990 101 CONTINUE
19995     RETURN
20000     END
20005 SUBROUTINE TNKDIM(L)
20010*    CALCULATES TANK DIMENSIONS.
20015 COMMON/TECH/NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
20020 LOGICAL NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
20025 INTEGER L
20030 COMMON/FLORTHK/FLORTHK
20035C
20040 COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
20045 LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
20050 COMMON/TKGEOM/HORIZ,VERT
20055 LOGICAL HORIZ,VERT
20060 COMMON/TANKDM/TLENGTH(3),TWIDTH(3),THEIGHT(3),UGTHGHT(3),
20065+AGTHGHT(3),DIAM(3),LENGTH(3)
20070 REAL TLENGTH,TWIDTH,THEIGHT,UGTHGHT,AGTHGHT,DIAM,LENGTH
20075 COMMON/TKINFO/FRACTUG,TNKCAP(3)
20080 REAL FRACTUG,TNKCAP
20085 COMMON/THICK/WALLTHK(3),TANK2(3)
20090 COMMON/EXTHI/WALLEX(3),WALLEX2(3)
20095 COMMON/WALL/TK2WALL,PI2WALL
20100 LOGICAL TK2WALL,PI2WALL
20105
20110 REAL WALLEX,WALLEX2
20115 IF  (CONCRT)  THEN
20120     IF  (TNKCAP(L).LE.3000)  THEN
20125         WALLTHK(L)=6
20130     ELSEIF  (TNKCAP(L).LE.10000)  THEN
20135         WALLTHK(L)=8
20140     ELSEIF  (TNKCAP(L).LE.20000)  THEN
20145         WALLTHK(L)=8
20150     ELSEIF  (TNKCAP(L).LE.50000)  THEN
20155         WALLTHK(L)=12
20160     ELSE
20165         WALLTHK(L)=15
20170     ENDIF
20175     IF  (VERT)  THEN
20180*****    CIRCULAR
20185   DIAM(L)=(.698*((1.005*TNKCAP(L))**(1/3.)))+(WALLTHK(L)/6.)
20190     LENGTH(L)=0.5*(DIAM(L)-(WALLTHK(L)/6.))
20195     ELSE
20200********    SQUARE
20205   LENGTH(L)=(.644*((1.005*TNKCAP(L))**(1/3.)))+(WALLTHK(L)/6.)
20210     DIAM(L)=0.5*(LENGTH(L)-(WALLTHK(L)/6.))
```

```
    ENDIF
      IF(TK2WALL)THEN
      DIAM(L)=DIAM(L)+2+WALLTHK(L)/6.
      LENGTH(L)=LENGTH(L)+WALLTHK(L)/6.+1
   ENDIF
 ELSEIF (HORIZ.AND.FRP) THEN
    DIAM(L)=0.4*((TNKCAP(L)*1.005)**(1/3.))
    LENGTH(L)=3*DIAM(L)
    IF (DIAM(L).LE.4) THEN
       WALLTHK(L)=0.25
    ELSEIF (DIAM(L).LE.5) THEN
       WALLTHK(L)=0.31
    ELSEIF (DIAM(L).LE.6) THEN
       WALLTHK(L)=0.44
    ELSEIF (DIAM(L).LE.8) THEN
       WALLTHK(L)=0.81
    ELSEIF (DIAM(L).LE.10) THEN
       WALLTHK(L)=1.25
    ELSEIF(DIAM(L).LE.12)THEN
       WALLTHK(L)=1.50
    ELSE
       WALLTHK(L)=1.75
    ENDIF
C
 ELSEIF (VERT.AND.FRP) THEN
    DIAM(L)=0.38*((TNKCAP(L)*1.005)**(1/3.))
    LENGTH(L)=3*DIAM(L)
    IF (DIAM(L).LE.4) THEN
       WALLTHK(L)=0.19
    ELSEIF (DIAM(L).LE.5) THEN
       WALLTHK(L)=0.25
    ELSEIF (DIAM(L).LE.6) THEN
       WALLTHK(L)=0.31
    ELSEIF (DIAM(L).LE.8) THEN
       WALLTHK(L)=0.44
    ELSEIF (DIAM(L).LE.10) THEN
       WALLTHK(L)=0.75
    ELSEIF(DIAM(L).LE.12)THEN
     WALLTHK(L)=1.12
   ELSE
       WALLTHK(L)=1.5
    ENDIF
 ELSE
  IF(TNKCAP(L).LE.50000)THEN
    DIAM(L)=0.44*((1.005*TNKCAP(L))**(1/3.))
    LENGTH(L)=2*DIAM(L)
  ELSEIF(TNKCAP(L).LE.375000)THEN
     DIAM(L)=0.652*(TNKCAP(L)*1.005)**(1./3.)
     LENGTH(L)=DIAM(L)
  ELSE
     DIAM(L)=0.554*(TNKCAP(L)*1.005)**(1./3.)
     LENGTH(L)=40
  ENDIF
    IF (TNKCAP(L).LE.10000) THEN
       WALLTHK(L)=0.25
    ELSEIF (TNKCAP(L).LE.20000) THEN
       WALLTHK(L)=0.31
    ELSEIF (TNKCAP(L).LE.30000) THEN
       WALLTHK(L)=0.38
    ELSEIF (TNKCAP(L).LE.100000) THEN
       WALLTHK(L)=0.50
    ELSE
       WALLTHK(L)=0.625
    ENDIF
ENDIF
IF(TK2WALL.AND..NOT.CONCRT)THEN
    DIAM(L)=DIAM(L)+(1+WALLTHK(L))/6.
    LENGTH(L)=LENGTH(L)+(1+WALLTHK(L))/6.
  ENDIF
TANK2(L)=WALLTHK(L)
WALLEX(L)=WALLTHK(L)
WALLEX2(L)=WALLTHK(L)
C
RETURN
END
SUBROUTINE CORERAT
* ESTIMATE THE INTERIOR GENERALIZED CORROSION RATE AND
* THE EXTERIOR GENERALIZED AND LOCALIZED CORROSION RATES.
COMMON/TKFRAC/TANKTIM(3)
REAL TANKTIM
COMMON/CRAD/CRADLE
LOGICAL CRADLE
COMMON/AREAS2/PIPESA(5)
REAL PIPESA
REAL TANKSA
COMMON/AREAS/TANKSA(3)
COMMON/PMATL/PCSTEEL,PSSTEEL
LOGICAL PCSTEEL,PSSTEEL
COMMON/OPDAY/OPDYYR
INTEGER OPDYYR
COMMON/OPHRS/OPHRSDY
REAL OPHRSDY
COMMON/DISCH/DISCRT(5),DISCTIM(5),DISCFR(5),VEHTANK,THRUPUT
REAL DISCRT,DISCTIM,DISCFR,VEHTANK,THRUPUT
COMMON/OPERAT/BATCH,CONT
LOGICAL BATCH,CONT
COMMON/TECH/NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
LOGICAL NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
COMMON/PIFRP/PFRP
LOGICAL PFRP
COMMON/LOOPCT/NPI,NTK
INTEGER NPI,NTK

COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT

COMMON/MATL/TNKMATL,PIPMATL
COMMON/ELOCAL/PIEXLOC(5),TKEXLOC(3),TKEXLO2(3)
REAL PIEXLOC,TKEXLOC,TKEXLO2
COMMON/EXTERN/EXCORLO
COMMON/CORE/PCORE(5),GCORE(5),PMCORE(5),TCORE(3),TCORE2(3)
COMMON/CORE1/PCORE2(5),PIEXT2(5),PIEXLO2(5)
REAL PCORE2,PIEXT2,PIEXLO2
INTEGER TNKMATL,PIPMATL
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```
20785 REAL PCORE,GCORE,PMCORE,TCORE,TCORE2
20790 REAL EXCORLO
20795 COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
20800 LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
20805 COMMON/WALL/TK2WALL,PI2WALL
20810 LOGICAL TK2WALL,PI2WALL
20815 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
20820 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
20825 COMMON/ECORE/PIEXT(5),TKEXT(3),PMEXT(5),TKEXT2(3)
20830 REAL PIEXT,TKEXT,PMEXT,TKEXT2
20835 COMMON/ITHICK/IPIPE(5),IPUMP(5),ITANK(3),IGASK(5),ITANK2(3)
20840 REAL IPIPE,IPUMP,ITANK,IGASK,ITANK2
20845 COMMON/MATPAR/APAR,CPAR,APARPI,CPARPI,APARPM,CPARPM
20850 REAL APAR,CPAR,APARPI,CPARPI,APARPM,CPARPM
20855 REAL THADJ
20860 COMMON/FILL/FILLRT(5),FILLTIM(5),FILLFR(5),FILLVOL(5)
20865 REAL FILLRT,FILLTIM,FILLFR,FILLVOL
20870 COMMON/VENT/VCORE,VENTI,VENTE,IVENT,VLOCAL,VNTLOC,VEXT,
20875+VEXTLOC
20880 REAL VNTLOC
20885 REAL VCORE,VENTI,VENTE,IVENT,VLOCAL,VEXT,VEXTLOC
20890
20895 ATMOS=.0014
20900 VCORE=ATMOS
20905 VEXT=EXTCOR(1,1,1,.19)
20910 VEXTLOC=EXCORLO
20915 DO 31 I=1,NPI
20920
20925     IF(.NOT.PFRP)THEN
20930         IF((I.EQ.1).OR.(.NOT.STORAGE))THEN
20935         IF(BATCH)THEN
20940         IF(I.EQ.1)THEN
20945          PCORE(I)=(CORER(I,1)-ATMOS)*FILLFR(I)*FILLTIM(I)/1440.+
20950+ (ATMOS*(1-FILLFR(I)*FILLTIM(I)/1440.))
20955 IF(PSSTEEL)PCORE(I)=(CORER(I,1)/4.-ATMOS)*FILLFR(I)*FILLTIM(I)/
20960+ 1440.+(ATMOS*(1-FILLFR(I)*FILLTIM(I)/1440.))
20965          ELSE
20970          PCORE(I)=(CORER(I,1)-ATMOS)*DISCFR(I)*DISCTIM(I)/1440.+
20975+ (ATMOS*(1-DISCFR(I)*DISCTIM(I)/1440.))
20980 IF(PSSTEEL)PCORE(I)=(CORER(I,1)/4.-ATMOS)*DISCFR(I)*DISCTIM(I)/
20985+ 1440.+(ATMOS*(1-DISCFR(I)*DISCTIM(I)/1440.))
20990     ENDIF
20995         ELSE
21000         PCORE(I)=(CORER(I,1)-ATMOS)*OPHRSDY/24.*OPDYYR/365.+
21005+ (ATMOS*(1-(OPHRSDY/24.*OPDYYR/365.)))
21010 IF(PSSTEEL)PCORE(I)=(CORER(I,1)/4.-ATMOS)*OPHRSDY/24.*OPDYYR/365.+
21015+ (ATMOS*(1-(OPHRSDY/24.*OPDYYR/365.)))
21020         ENDIF
21025         IF(PCORE(I).LT.O.)PCORE(I)=ATMOS
21030         ELSE
21035         PCORE(I)=(CORER(I,1)-ATMOS)*DISCFR(I)*DISCTIM(I)/1440.+
21040+    (ATMOS*(1-DISCFR(I)*DISCTIM(I)/1440.))
21045 IF(PSSTEEL)PCORE(I)=(CORER(I,1)/4.-ATMOS)*DISCFR(I)*DISCTIM(I)/
21050+  1440.+(ATMOS*(1-DISCFR(I)*DISCTIM(I)/1440.))
21055         ENDIF
21060*    10.47FT2=SURFACE AREA OF 20 FT PIPE
21065   PIEXT(I)=EXTCOR(I,PIPMATL,1,.19)
```

```
     PIEXLOC(I)=EXCORLO*(PIPESA(I)/10.47)**.16
 IF(AGPIPE) PIEXLOC(I)=EXCORLO*(.05*PIPESA(I)/10.46)**.16
    ELSE
    PCORE(I)=0.
    PIEXT(I)=0.
    PIEXLOC(I)=0.
    ENDIF
 IF(PI2WALL)THEN
    IF(.NOT.PFRP)THEN
       PCORE2(I)=0.
       PIEXT2(I)=PIEXT(I)
       PIEXT(I)=0.
       PIEXLO2(I)=PIEXLOC(I)
       PIEXLOC(I)=0.
    ELSE
       PCORE(I)=0.
       PCORE2(I)=0.
       PIEXT2(I)=0.
       PIEXLO2(I)=0.
       PIEXT(I)=0.
       PIEXLOC(I)=0.
    ENDIF
ENDIF
       GCORE(I)=CORER(I,5)
       IF(AGPUMP)THEN
         PMCORE(I)=CORER(I,2)
          PMEXT(I)=ATMOS
          ELSE
           PMCORE(I)=0
           PMEXT(I)=0
       ENDIF
 31 CONTINUE
DO 31111 I=1,NTK
       IF(.NOT.(FRP.OR.CONCRT))THEN
   IF(STORAGE)THEN
   TCORE(I)=CORER(I,3)*TANKTIM(I)+ATMOS*(1-TANKTIM(I))
IF(SSTEEL)TCORE(I)=(CORER(I,3)/4.)*TANKTIM(I)+ATMOS*(1-
+TANKTIM(I))
   ELSE
   TCORE(I)=CORER(I+1,3)*TANKTIM(I)+ATMOS*(1-TANKTIM(I))
IF(SSTEEL)TCORE(I)=(CORER(I+1,3)/4.)*TANKTIM(I)+ATMOS*(1-
+TANKTIM(I))
   ENDIF
         TKEXT(I)=EXTCOR(I,TNKMATL,3,.25)
*  446FT2=SURFACE AREA OF A 5000 GALLON TANK
         TKEXLOC(I)=EXCORLO*(TANKSA(I)/446.)**.16
IF(AGTANK.AND.CRADLE)TKEXLOC(I)=EXCORLO*(.05*TANKSA(I)/446.)**.16
         ELSE
         TCORE(I)=0.
         TKEXT(I)=0.
         TKEXLOC(I)=0.
         ENDIF
   IF(TK2WALL)THEN
   IF(.NOT.(FRP.OR.CONCRT))THEN
   IF(STORAGE)THEN
  TCORE(I)=CORER(I,3)*TANKTIM(I)+ATMOS*(1-TANKTIM(I))
IF(SSTEEL)TCORE(I)=(CORER(I,3)/4.)*TANKTIM(I)+ATMOS*(1-
21355+TANKTIM(I))
21360     ELSE
21365     TCORE(I)=CORER(I+1,3)*TANKTIM(I)+ATMOS*(1-TANKTIM(I))
21370  IF(SSTEEL) TCORE(I)=(CORER(I+1,3)/4.)*TANKTIM(I)+ATMOS*(1-
21375+TANKTIM(I))
21380     ENDIF
21385         TCORE2(I)=0
21390             TKEXT2(I)=EXTCOR(I,TNKMATL,3,.25)
21395             TKEXLO2(I)=EXCORLO*(TANKSA(I)/446.)**.16
21400  IF(AGTANK.AND.CRADLE) TKEXLOC(I)=EXCORLO*(.05*TANKSA(I)/446.)**.16
21405             TKEXT(I)=0
21410             TKEXLOC(I)=0
21415     ELSE
21420     TCORE(I)=0.
21425     TCORE2(I)=0.
21430     TKEXT2(I)=0.
21435     TKEXLO2(I)=0.
21440     TKEXT(I)=0.
21445     TKEXLOC(I)=0.
21450     ENDIF
21455     ENDIF
21460 31111 CONTINUE
21465 IF(CYNOX.OR.CHRED.OR.PRECIP)
21470+ TCORE(2)=(TCORE(2)+TCORE(1))/2.
21475 RETURN
21480 END
21485 REAL FUNCTION CORER(STAGE,COMP)
21490*  THIS ROUTINE ESTIMATES THE GENERALIZED COROSION/EROSION RATES.
21495 COMMON/SUSPSOL/SUSSOL(5)
21500 REAL SUSSOL
21505 COMMON/PH/PH(5)
21510 REAL PH
21515 REAL SUSPPM
21520
21525 COMMON/INCOMP/INCFACT
21530 COMMON/AX/IY
21535 REAL COR(5),ERO(5)
21540 INTEGER IY,STAGE,COMP
21545 REAL RAND,INCFACT
21550C  TREATMENT STAGES
21555C  1=INTLET PIPE,PUMP,ETC
21560C  2=TANK1,DISCHARGE FROM TANK1(INCLUDES TOP PRODUCTS)
21565C   3=TANK2,DISCHARGE FROM TANK2
21570C   4=TANK3,DISCHARGE FROM TANK3
21575C   5=BOTTOMS DISCHARGE
21580C  COMPONENTS
21585C  1=PIPE
21590C  2=PUMP
21595C  3=TANK
21600C  5=GASKET
21605 COR(STAGE)=0.
21610 ERO(STAGE)=0.
21615 SUSPPM=SUSSOL(STAGE)*10.E+06
21620 IF(COMP.NE.5) THEN
21625     IF(PH(STAGE).LE.5) THEN
21630         COR(STAGE)=FNU(.02,.035)
21635     ELSEIF(PH(STAGE).GT.5.AND.PH(STAGE).LT.10) THEN
```

```
 RAND=RAN (IY)
IF (RAND.LT.0.65)  THEN
COR (STAGE) =0.002
GO TO 100
ELSEIF ((RAND.GE..65) .AND. (RAND.LT..90)) THEN
COR (STAGE) =FNU (.002, .01)
GO TO 100
ELSE
COR (STAGE) =FNU (.01, .02)
GO TO 100
ENDIF
ELSE
*   ELSE PH GREATER THAN OR EQUAL TO 10
    COR (STAGE) =0.
ENDIF
ENDIF
100 CONTINUE
IF (COMP.EQ.2)  THEN
IF (SUSPPM.GT.10000) THEN
ERO (STAGE) =FNU (0., .010)
ELSE
    ERO (STAGE) =FNU (.010, .020)
ENDIF
ENDIF
IF (COMP.EQ.1)  THEN
IF (SUSPPM.LE.10000) THEN
    ERO (STAGE) =FNU (.005, .01)
ELSEIF (SUSPPM.GT.0) THEN
ERO (STAGE) =FNU (0., .005)
ELSE
    ERO (STAGE) =0.
ENDIF
ENDIF
IF (COMP.EQ.5) THEN
*   ESTIMATE OF EROSION AND AGING
    RAND=RAN (IY)
    IF (RAND.LE..77) THEN
        ERO (STAGE) =FNU (0., .0125)
    ELSEIF ((RAND.GT..77) .AND. (RAND.LE..83)) THEN
        ERO (STAGE) =FNU (.0125, .025)
    ELSE
        ERO (STAGE) =FNU (.025, .05)
    ENDIF
ENDIF
IF (COMP.EQ.5) THEN
CORER=INCFACT*ERO (STAGE)
ELSE
CORER=COR (STAGE) +ERO (STAGE)
ENDIF
RETURN
END
FUNCTION EXTCOR (LOC, MATL, COMP, ITHCK)
*   THIS FUNCTION ESTIMATES THE EXTERIOR GENERALIZED AND LOCALIZED
* CORROSION RATES.
INTEGER LOC
COMMON/SAV/SAV
REAL SAV
```

```
COMMON/CRAD/CRADLE
LOGICAL CRADLE
COMMON/EXTERN/EXCORLO
COMMON/TKINFO/FRACTUG,TNKCAP(3)
REAL FRACTUG,TNKCAP
COMMON/DC/DCFACT
COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
REAL DCFACT
REAL ATMOS
REAL MATLFAC
 REAL EXCORLO,GENCOR
REAL ITHCK
 INTEGER MATL,COMP
ATMOS=.0014
IF((MATL.EQ.1).OR.(MATL.EQ.2))THEN
MATLFAC=1.0
IF(MATL.EQ.2)MATLFAC=4.0
EXCORLO=(ITHCK/AGEEST(LOC,COMP))*DCFACT/MATLFAC
IF((VAULT.OR.(AGTANK.AND.CRADLE)).AND.(COMP.EQ.3))THEN
    GENCOR=ATMOS
    GO TO 6037
ENDIF
**** WATCH FOR CHANGES TO PIPE SECON.  CONT.  OPTIONS***
IF(((PIPSEC.AND.AGPIPE).OR.AGPIPE).AND.(COMP.EQ.1))THEN
    GENCOR=ATMOS
    GO TO 6037
ENDIF
GENCOR=MAX(FNU(.0014,.005)*(SAV/10.),.0014)*DCFACT/MATLFAC
6037 CONTINUE
IF(GENCOR.GT.EXCORLO)THEN
    EXCORLO=0.
  ELSE
EXCORLO=EXCORLO-GENCOR
ENDIF
EXTCOR=GENCOR
ELSE
  EXTCOR=0.
  EXCORLO=0.
ENDIF
RETURN
END
SUBROUTINE CORPRB
* THIS ROUTINE SAMPLES THE INCOMPATABILITY/AGING FACTOR
* FOR GASKETS.
COMMON/INCOMP/INCFACT
REAL INCFACT
* GASKETS ONLY
    INCFACT=FNU(1.0,20.0)

RETURN
END
SUBROUTINE INTCORR
* THIS ROUTINE ESTIMATES THE INTERIOR LOCALIZED CORROSION RATE.
COMMON/AREAS2/PIPESA(5)
```

```
22210 REAL PIPESA
22215 REAL TANKSA
22220 COMMON/AREAS/TANKSA(3)
22225 COMMON/LOOPCT/NPI,NTK
22230 INTEGER NPI,NTK
22235 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
22240 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
22245
22250 COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
22255 LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
22260 COMMON/CORE/PCORE(5),GCORE(5),PMCORE(5),TCORE(3),TCORE2(3)
22265 COMMON/CORE1/PCORE2(5),PIEXT2(5),PIEXLO2(5)
22270 REAL PCORE2,PIEXT2,PIEXLO2
22275 COMMON/LIFCOR/LIFCOR(2,5)
22280 COMMON/ITHICK/IPIPE(5),IPUMP(5),ITANK(3),IGASK(5),ITANK2(3)
22285 REAL IPIPE,IPUMP,ITANK,IGASK,ITANK2
22290 COMMON/ILOCAL/PILOCAL(5),PMLOCAL(5),TKLOCAL(3),TKLOCA2(3)
22295 REAL PILOCAL,PMLOCAL,TKLOCAL,TKLOCA2
22300 REAL PCORE,GCORE,PMCORE,TCORE,TCORE2
22305 REAL LIFCOR
22310 REAL PIPLOC(5),PMPLOC(5),TNKLOC(3)
22315 REAL THADJ
22320 COMMON/MATPAR/APAR,CPAR,APARPI,CPARPI,APARPM,CPARPM
22325 REAL APAR,CPAR,APARPI,CPARPI,APARPM,CPARPM
22330 COMMON/VENT/VCORE,VENTI,VENTE,IVENT,VLOCAL,VNTLOC,VEXT,
22335+VEXTLOC
22340 REAL VNTLOC
22345 REAL VCORE,VENTI,VENTE,IVENT,VLOCAL,VEXT,VEXTLOC
22350
22355
22360 VNTLOC=0
22365 DO 7777 L=1,3
22370 TNKLOC(L)=0
22375 TKLOCAL(L)=0
22380 TKLOCA2(L)=0
22385 7777 CONTINUE
22390    DO 777 L=1,5
22395    PIPLOC(L)=0
22400    PMPLOC(L)=0
22405       PILOCAL(L)=0.
22410       PMLOCAL(L)=0.
22415    777 CONTINUE
22420       VLOCAL=0.
22425 IF(VNTLOC.EQ.0)THEN
22430    VNTLOC=FNB(LIFCOR(1,5))
22435    IF(VNTLOC.EQ.1)THEN
22440       THADJ=IVENT/.25
22445       VLOCAL=(IVENT/FNN(8.*APARPI*THADJ,5*APARPI))-VCORE
22450       IF(VLOCAL.LT.0)VLOCAL=0.
22455    ENDIF
22460 ENDIF
22465 DO 32 I=1,NPI
22470 IF(PIPLOC(I).EQ.0)THEN
22475    PIPLOC(I)=FNB(LIFCOR(1,5)*((PIPESA(I)/10.47)**.16))
22480    IF(PIPLOC(I).EQ.1)THEN
22485       THADJ=IPIPE(I)/.25
22490   PILOCAL(I)=((IPIPE(I)/FNN(8.*APARPI*THADJ,5*APARPI))-PCORE(I)
22495+    )*(PIPESA(I)/10.47)**.16
22500           IF(PILOCAL(I).LT.O.)PILOCAL(I)=O.
22505      ENDIF
22510 ENDIF
22515 IF(AGPUMP) THEN
22520 IF(PMPLOC(I).EQ.0)THEN
22525      PMPLOC(I)=FNB(LIFCOR(1,5))
22530      IF(PMPLOC(I).EQ.1)THEN
22535         THADJ=IPUMP(I)/.25
22540    PMLOCAL(I)=(IPUMP(I)/FNN(8.*APARPM*THADJ,5*APARPM))-PMCORE(I)
22545         IF(PMLOCAL(I).LT.O.)PMLOCAL(I)=O.
22550      ENDIF
22555 ENDIF
22560       ELSE
22565          PMLOCAL(I)=0
22570       ENDIF
22575 IF(I.LE.NTK)THEN
22580      IF(TNKLOC(I).EQ.O)THEN
22585          TNKLOC(I)=FNB(LIFCOR(1,1))
22590          IF(TNKLOC(I).EQ.1)THEN
22595              THADJ=ITANK(I)/.25
22600          TKLOCAL(I)=(ITANK(I)/FNN(8.*APAR,5.*APAR))-TCORE(I)
22605          IF((TKLOCAL(I).LT.O.).OR.FRP)TKLOCAL(I)=O.
22610          ENDIF
22615     ENDIF
22620 ENDIF
22625 32 CONTINUE
22630 RETURN
22635 END
22640 SUBROUTINE THLOSS(THICKI,THICKE,GENINT,GENEXT,LOCINT,
22645+       LOCEXT,COMP,LOC)
22650*    'THLOSS' SUBTRACTS THE INTERIOR AND EXTERIOR CORROSION
22655* RATES FROM THE COMPONENT'S PRESENT WALL THICKNESS.
22660 COMMON/IYRNO/IYRNUM
22665*
22670 INTEGER COMP
22675 COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
22680 LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
22685 COMMON/COATS/COATING(4,3,5)
22690 LOGICAL COATING
22695 REAL THICKI,THICKE,GENINT,GENEXT,LOCINT,LOCEXT
22700 COMMON/COATIM/ICOATIM(3,5),ECOATIM(3,5)
22705 REAL ICOATIM,ECOATIM
22710 COMMON/CATHOD/CATFAIL
22715 LOGICAL CATFAIL
22720 COMMON/CATHLOS/CATHLOS
22725 REAL CATHLOS
22730 INTEGER IYRNUM
22735 IF((.NOT.COATING(4,COMP,1)).AND.(.NOT.CATSTEL))THEN
22740 IF((ICOATIM(COMP,LOC).LE.IYRNUM).AND.(ECOATIM(COMP,LOC)
22745+.LE.IYRNUM))THEN
22750          THICKI=THICKI-GENINT-GENEXT-LOCINT
22755          THICKE=THICKE-GENINT-GENEXT-LOCEXT
22760        ELSEIF(ICOATIM(COMP,LOC).LE.IYRNUM)THEN
22765          THICKI=THICKI-GENINT-GENEXT-LOCINT
22770        ELSEIF(ECOATIM(COMP,LOC).LE.IYRNUM)THEN
22775          THICKE=THICKE-GENINT-GENEXT-LOCEXT
```

```
22780      ELSE
22785*     NO CORROSION/EROSION
22790    ENDIF
22795   ELSEIF((.NOT.COATING(4,COMP,1)).AND.CATSTEL)THEN
22800    IF(CATFAIL)THEN
22805 IF((ICOATIM(COMP,LOC).LE.IYRNUM).AND.(ECOATIM(COMP,LOC)
22810+.LE.IYRNUM))THEN
22815       THICKI=THICKI-GENINT-GENEXT-LOCINT
22820       THICKE=THICKE-GENINT-GENEXT-LOCEXT
22825      ELSEIF(ICOATIM(COMP,LOC).LE.IYRNUM)THEN
22830       THICKI=THICKI-GENINT-GENEXT-LOCINT
22835      ELSEIF(ECOATIM(COMP,LOC).LE.IYRNUM)THEN
22840       THICKE=THICKE-GENINT-GENEXT-LOCEXT
22845      ELSE
22850*      NO CORROSION/EROSION
22855    ENDIF
22860    ELSE
22865 IF((ICOATIM(COMP,LOC).LE.IYRNUM).AND.(ECOATIM(COMP,LOC)
22870+.LE.IYRNUM))THEN
22875          THICKI=THICKI-CATHLOS
22880          THICKE=THICKE-CATHLOS
22885         ELSEIF(ICOATIM(COMP,LOC).LE.IYRNUM)THEN
22890          THICKI=THICKI-CATHLOS
22895         ELSEIF(ECOATIM(COMP,LOC).LE.IYRNUM)THEN
22900          THICKE=THICKE-CATHLOS
22905         ELSE
22910*            NO CORROSION
22915       ENDIF
22920    ENDIF
22925   ELSEIF(CATSTEL)THEN
22930    IF(CATFAIL)THEN
22935       THICKI=THICKI-GENINT-GENEXT-LOCINT
22940       THICKE=THICKE-GENINT-GENEXT-LOCEXT
22945      ELSE
22950       THICKI=THICKI-CATHLOS
22955       THICKE=THICKE-CATHLOS
22960    ENDIF
22965   ELSE
22970*   NO PROTECTION AGAINST CORROSION/EROSION
22975    THICKI=THICKI-GENINT-GENEXT-LOCINT
22980    THICKE=THICKE-GENINT-GENEXT-LOCEXT
22985 ENDIF
22990 RETURN
22995 END
23000 FUNCTION FNN(AVG,STD)
23005* THIS FUNCTION SAMPLES A NORMAL PROBABILITY DISTRIBUTION.
23010 COMMON/AX/IY
23015 10 R1=RAN(IY)*2.-1.
23020 R2=RAN(IY)*2.-1.
23025 T=R1*R1+R2*R2
23030 IF(T.GT.1.) GO TO 10
23035 C=SQRT(-2.*ALOG10(T)/T)
23040 FNN=AVG+STD*C*R1
23045 IF(FNN.LE.0)FNN=.01
23050 RETURN
23055 END
23060 FUNCTION FNBE(XM,XL,XU)
```

```
23065*EMPIRICAL BETA DISTRIBUTION
23070 XME=(XL+XU+4.0*XM)/6.0
23075 STD=(XU-XL)/6.0
23080 XMU=(XME-XL)/(XU-XL)
23085 VAR=(STD/(XU-XL))*(STD/(XU-XL))
23090 A=(XMU**2.0-XMU**3.0-VAR*XMU)/VAR
23095 B=(XMU-2.0*XMU**2.0+XMU**3.0+VAR*XMU-VAR)/VAR
23100 X1=FNG(A,1.)
23105 X2=FNG(B,1.)
23110 X3=X1/(X1+X2)
23115 FNBE=XL+(XU-XL)*X3
23120 RETURN
23125 END
23130 FUNCTION FNG(A,B)
23135 COMMON/AC/IY
23140 II=A
23145 AA=FLOAT(II)
23150 T=ABS(AA-A)
23155 IF(T.EQ.0.)GO TO 50
23160 IF((A.GT.0.).AND.(A.LT.1.))GO TO 20
23165 IF((A.GE.1.).AND.(A.LT.5.))GO TO 30
23170 R=RAN(IY)
23175 T=ABS(AA-A)
23180 IF(R.GE.T) GO TO 10
23185 AA=AA+1
23190 10 FNG=FNER(B,AA)
23195 RETURN
23200 20 X=RAN(IY)**(1./A)
23205 Y=RAN(IY)**(1./(1.-A))
23210 Z=X+Y
23215 IF(Z.GT.1.)GO TO 20
23220 W=X/(X+Y)
23225 FNG=-W*ALOG(RAN(IY))*B
23230 RETURN
23235 30 II=A
23240 AA=FLOAT(II)
23245 BB=ABS(AA-A)
23250 35 SUM=1.
23255 DO 40 I=1,II
23260 40 SUM=SUM*RAN(IY)
23265 X=-(A/AA)*ALOG(SUM)
23270 R=RAN(IY)
23275 T=((X/A)**BB)*EXP(-BB*INT((X/A)-1.)-1.)
23280 IF(R.GT.T)GO TO 35
23285 FNG=X*B
23290 RETURN
23295 50 FNG=FNER(B,AA)
23300 RETURN
23305 END
23310 FUNCTION FNER(A,B)
23315 COMMON/AX/IY
23320 K=B
23325 SUM=1.
23330 DO 10 I=1,K
23335 10 SUM=SUM*RAN(IY)
23340 FNER=-A*ALOG(SUM)
23345 RETURN
```

```
END
  SUBROUTINE CATREL
*   THIS ROUTINE SAMPLES THE PROBABILITY OF CATASTROPHIC FAILURE
*  AND SAMPLES THEIR TIME OF FAILURE.
     COMMON/CATREL/ANUCAT(2,7),IGPROD
     REAL ANUCAT,IGPROD
COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP

LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPUMP,AGPIPE
COMMON/CATAST/CATASTR(12)
INTEGER CATASTR

COMMON/CATAS/VANDAL,WIND,EARTHQU,FLOOD,FIREXPL,FIRE
INTEGER VANDAL,WIND,EARTHQU,FLOOD,FIREXPL,FIRE
        N=7
     DO 50 I=2,N
        ANUCAT(2,I)=FNB(ANUCAT(1,I))
     50 CONTINUE
   VANDAL=0
   WIND=0
   EARTHQU=0
    FIREXPL=0
    FIRE=0
     FLOOD=0
IF(AGTANK.OR.IGTANK)THEN
   IF(ANUCAT(2,2).EQ.1)THEN
   CALL FTIME(VANDAL)
   CATASTR(VANDAL)=VANDAL
   ENDIF
   IF(ANUCAT(2,3).EQ.1)THEN
   CALL FTIME(WIND)
   CATASTR(WIND)=WIND
   ENDIF
ENDIF
IF(ANUCAT(2,4).EQ.1)THEN
   CALL FTIME(EARTHQU)
   CATASTR(EARTHQU)=EARTHQU
ENDIF
IF((ANUCAT(2,6).EQ.1).AND.(IGPROD.EQ.1))THEN
   CALL FTIME(FIREXPL)
   CATASTR(FIREXPL)=FIREXPL
ENDIF
IF(ANUCAT(2,7).EQ.1)THEN
   CALL FTIME(FIRE)
   CATASTR(FIRE)=FIRE
ENDIF
IF(AGTANK.OR.IGTANK)THEN
  IF(ANUCAT(2,5).EQ.1)THEN
   CALL FTIME(FLOOD)
   CATASTR(FLOOD)=FLOOD
  ENDIF
ENDIF
  RETURN
  END
REAL FUNCTION RUPTURE(COMP,IYRNUM)
*   THIS FUNCTION SAMPLES THE RUPTURE FAULT TREE FOR
* COMPONENT RUPTURE.
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COMMON/DEFPROB/LIFDEF(2,7),GSKINC(2)
REAL LIFDEF,GSKINC
COMMON/OPCL/OPEN,CLOSED
LOGICAL OPEN,CLOSED
REAL SUPFAIL,EXLIQ,OVERPR,LOADRUP,SETLING
REAL VIBTOR
INTEGER COMP,IYRNUM
COMMON/RUPT2/YRPVON(2),YRVLON(2)
COMMON/RUPT1/OPCOM(2),PRESREL(2)
COMMON/RUPPROB/TNKRUP2(2),TNKRUP(2),WLDRUP(2),PIPRUP(2),PORTHOS(2)
COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
REAL YRPVON,YRVLON,OPCOM,PRESREL
REAL TNKRUP2,TNKRUP,WLDRUP,PIPRUP,PORTHOS
LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
IF(CLOSED.AND.(COMP.EQ.3))THEN
  IF(.NOT.UGTANK)THEN
   YRPVON(2)=FNB(YRPVON(1))
  ELSE
   YRPVON(2)=0.
  ENDIF
   YRVLON(2)=FNB(YRVLON(1))
   SUPFAIL=1-(1-YRPVON(2))*(1-YRVLON(2))
   OPCOM(2)=FNB(OPCOM(2))
   EXLIQ=1-(1-SUPFAIL)*(1-OPCOM(2))
   PRESREL(2)=FNB(PRESREL(1))
   OVERPR=PRESREL(2)*EXLIQ
ELSE
   OVERPR=0
ENDIF
   IF(COMP.EQ.1)THEN
      PIPRUP(2)=FNB(PIPRUP(1))
      TNKRUP(2)=0
      WLDRUP(2)=0
   ELSEIF(COMP.EQ.3)THEN
      TNKRUP(2)=FNB(TNKRUP(1))
      PIPRUP(2)=0
      WLDRUP(2)=0
   ELSE
      WLDRUP(2)=FNB(WLDRUP(1))
      TNKRUP(2)=0
      PIPRUP(2)=0
   ENDIF
   LOADRUP=MAX(PIPRUP(2),TNKRUP(2),WLDRUP(2))
SETLING=0
IF(IYRNUM.EQ.1)THEN
   IF(COMP.EQ.1)THEN
      IF(UGPIPE)THEN
         LIFDEF(2,6)=FNB(LIFDEF(1,6))
         LIFDEF(2,7)=FNB(LIFDEF(1,7))
         SETLING=1-(1-LIFDEF(2,6))*(1-LIFDEF(2,7))
      ENDIF
   ENDIF
   IF((COMP.EQ.3).OR.(COMP.EQ.5))THEN
      IF(UGTANK.OR.IGTANK)THEN
         LIFDEF(2,6)=FNB(LIFDEF(1,6))
         LIFDEF(2,7)=FNB(LIFDEF(1,7))
         SETLING=1-(1-LIFDEF(2,6))*(1-LIFDEF(2,7))
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23920        ENDIF
23925    ENDIF
23930 ENDIF
23935 IF((COMP.EQ.1).AND.AGPIPE)THEN
23940    LIFDEF(2,1)=FNB(LIFDEF(1,1))
23945    LIFDEF(2,2)=FNB(LIFDEF(1,2))
23950    VIBTOR=1-(1-LIFDEF(2,1))*(1-LIFDEF(2,2))
23955  ELSE
23960    VIBTOR=0
23965 ENDIF
23970 RUPTURE=1-(1-OVERPR)*(1-LOADRUP)*(1-SETLING)*(1-VIBTOR)
23975 RETURN
23980 END
23985 SUBROUTINE OVERFLW(L,OFLOW)
23990*   THIS ROUTINE IS SAMPLED MONTHLY FOR THE PROBABILITY OF
23995* AN OVERFLOW EVENT OCCURRING.
24000 COMMON/OFL5/OPVLOE(2),OPVLON(2)
24005 REAL OPVLOE,OPVLON
24010 INTEGER L
24015 COMMON/PH/PH(5)
24020 REAL PH
24025 COMMON/OPERAT/BATCH,CONT
24030 LOGICAL BATCH,CONT
24035 COMMON/MOF/MOFILL(2)
24040 REAL MOFILL
24045 COMMON/SHUT/AUTSHUT
24050 LOGICAL AUTSHUT
24055 COMMON/OPR1/AUTOMAT,MANUAL
24060 LOGICAL MANUAL,AUTOMAT
24065 INTEGER OFLOW
24070 COMMON/OFL1/OFTRCOM(2),OFTROM(2)
24075 COMMON/OFL2/MOPMOE(2),MOPVON(2),MOVLOE(2),MOVLON(2)
24080 COMMON/OFL3/MOPMCE(2),MOPMCN(2),MOVLCE(2),MOVLCN(2)
24085 COMMON/OFL4/MOALARM(2),FLVCN2(2),LEVIN2(2),FLVCN1(2),OPCOMM(2)
24090 REAL OFTRCOM,OFTROM
24095 REAL MOPMOE,MOPVON,MOVLOE,MOVLON
24100 REAL MOPMCE,MOPMCN,MOVLCE,MOVLCN
24105 REAL MOALARM,FLVCN2,LEVIN2,FLVCN1,OPCOMM
24110 COMMON/OVER/MOLEVIN(2)
24115 REAL MOLEVIN
24120 REAL OPMALF,FSYSHUT,OFTR,PMFAILU,VLFAILU,SDFAIL
24125 REAL PMFAILD,VLFAILD,SUFAIL,MECHFAL,FLTORES
24130 REAL MSSF,FLVCNSY,AEMSHSY
24135 COMMON/TECH/NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
24140 LOGICAL NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
24145 OFLOW=0
24150 MOLEVIN(2)=FNB(MOLEVIN(1))
24155 OPCOMM(2)=FNB(OPCOMM(1))
24160 FLVCN1(2)=FNB(FLVCN1(1))
24165 OFTRCOM(2)=FNB(OFTRCOM(1))
24170 OFTROM(2)=FNB(OFTROM(1))
24175 MOPMOE(2)=FNB(MOPMOE(1))
24180 MOPVON(2)=FNB(MOPVON(1))
24185 MOVLOE(2)=FNB(MOVLOE(1))
24190 MOVLON(2)=FNB(MOVLON(1))
24195 MOPMCE(2)=FNB(MOPMCE(1))
24200 MOPMCN(2)=FNB(MOPMCN(1))
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24205 MOVLCE (2) =FNB (MOVLCE (1))
24210 MOVLCN (2) =FNB (MOVLCN (1))
24215 MOALARM (2) =FNB (MOALARM (1))
24220 FLVCN2 (2) =FNB (FLVCN2 (1))
24225 LEVIN2 (2) =FNB (LEVIN2 (1))
24230 MOFILL (2) =FNB (MOFILL (1))
24235 OPVLON (2) =FNB (OPVLON (1))
24240 OPVLOE (2) =FNB (OPVLOE (1))
24245 IF (PH (L) .LE.4.5) THEN
24250      MOPVON (2) =0.
24255      MOVLON (2) =0.
24260      MOPMCN (2) =0.
24265      MOVLCN (2) =0.
24270      OPVLON (2) =0.
24275 ELSE
24280      MOPMOE (2) =0.
24285      MOVLOE (2) =0.
24290      MOPMCE (2) =0.
24295      MOVLCE (2) =0.
24300      OPVLOE (2) =0.
24305 ENDIF
24310 IF (MOFILL (2) .EQ. 1) THEN
24315 IF (AUTOMAT) THEN
24320      OPMALF=1- (1-MOLEVIN (2)) * (1-FLVCN1 (2)) * (1-OPCOMM (2))
24325+     * (1-OPVLON (2)) * (1-OPVLOE (2))
24330 ELSE
24335      OPMALF=1- (1-MOLEVIN (2)) * (1-OPCOMM (2))
24340 ENDIF
24345 IF (OPMALF.EQ. 1) THEN
24350 OFTR=1- (1-OFTRCOM (2)) * (1-OFTROM (2))
24355      PMFAILU=1- (1-MOPMOE (2)) * (1-MOPVON (2))
24360      VLFAILU=1- (1-MOVLOE (2)) * (1-MOVLON (2))
24365      SUFAIL=PMFAILU*VLFAILU
24370 IF (.NOT.STORAGE) THEN
24375 PMFAILD=1- (1-MOPMCE (2)) * (1-MOPMCN (2))
24380 VLFAILD=1- (1-MOVLCE (2)) * (1-MOVLCN (2))
24385 IF (BATCH) THEN
24390      SDFAIL=1- (1-PMFAILD) * (1-VLFAILD)
24395 ELSE
24400 SDFAIL=PMFAILD
24405 ENDIF
24410 ELSE
24415      SDFAIL=1.
24420 ENDIF
24425 MECHFAL=SUFAIL*SDFAIL
24430 FLTORES=1- (1-OFTR) * (1-MECHFAL)
24435 MSSF=1- (1-FLTORES) * (1-MOALARM (2))
24440 IF (AUTSHUT) THEN
24445      IF (.NOT.STORAGE) THEN
24450          FLVCNSY=1- (1-SUFAIL*SDFAIL) * (1-FLVCN2 (2))
24455      ELSE
24460          FLVCNSY=1- (1-SUFAIL)
24465      ENDIF
24470      AEMSHSY=1- (1-LEVIN2 (2)) * (1-FLVCNSY)
24475 ELSE
24480      AEMSHSY=1
24485 ENDIF
```

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24490 FSYSHUT=AEMSHSY*MSSF
24495 IF(FSYSHUT.EQ.1)THEN
24500    OFLOW=OFLOW+1
24505 ENDIF
24510 ENDIF
24515 ENDIF
24520 RETURN
24525 END
24530 SUBROUTINE RELEASE(IFAC,YR,YRO)
24535*   'RELEASE' SIZES THE FAILURE EVENTS BY SAMPLING A LEAK RATE
24540* FOR EACH FAILURE EVENT AND SAMPLING A TIME OF DETECTION.  CORROSION
24545* LEAK RATES GROW WITH TIME AND DETECTION TIMES ARE A FUNCTION OF
24550* DETECTION OPTIONS SELECTED, DETECTION SAMPLING FREQUENCIES, LEAK
24555* RATES,AND VOLUME LOSSES.
24560 COMMON/RETR/RETROFT
24565 LOGICAL RETROFT
24570 LOGICAL PICFAIL,TKCFAIL
24575 COMMON/LEVOP/OPLEV
24580 REAL OPLEV
24585 COMMON/TKFRAC/TANKTIM(3)
24590 REAL TANKTIM
24595 COMMON/WINSP/WEEKINS
24600 LOGICAL WEEKINS
24605 REAL IFRAC,NOOFDAY
24610 COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
24615 LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
24620 COMMON/CRAD/CRADLE
24625 LOGICAL CRADLE
24630 COMMON/TKGEOM/HORIZ,VERT
24635 LOGICAL HORIZ,VERT
24640 COMMON/PIPCON/DIKE,CURB,ASPAD,COPAD,PLINER
24645 LOGICAL DIKE,CURB,ASPAD,COPAD,PLINER
24650 COMMON/TECH/NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
24655 LOGICAL NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
24660 COMMON/OPERAT/BATCH,CONT
24665 LOGICAL BATCH,CONT
24670 COMMON/PI2TIM/DIKTIM(5),CURTIM(5),PASPTIM(5),PCOPTIM(5),PLINTIM(5)
24675 REAL DIKTIM,CURTIM,PASPTIM,PCOPTIM,PLINTIM
24680 COMMON/ELOCAL/PIEXLOC(5),TKEXLOC(3),TKEXLO2(3)
24685 REAL PIEXLOC,TKEXLOC,TKEXLO2
24690 COMMON/CONPERM/PERMREL(3)
24695 REAL PERMREL
24700 COMMON/MOINV/MINV,MINT
24705 REAL MINV
24710 INTEGER MINT
24715 COMMON/LKLEN/PILKWID(5),PILKLEN(5)
24720 REAL PILKWID,PILKLEN
24725       COMMON/AX/IY
24730 COMMON/PIPELK/INTLK(5),PIPAGE(5),NUMLK(5),PRAN(5)
24735 INTEGER INTLK,NUMLK,PIPAGE
24740 REAL PRAN
24745 INTEGER OFLOW
24750 COMMON/THICK/TANKI(3),TANK2I(3)
24755 REAL TANKI,TANK2I
24760 COMMON/EXTHI/TANKE(3),TANK2E(3)
24765 REAL TANKE,TANK2E
24770 COMMON/EXTHICK/PIPEE(5),PUMPE(5),GASKE(5),PIPE2E(5),PIPE2I(5)
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24775 REAL PIPEE,PUMPE,GASKE,PIPE2E,PIPE2I
24780 COMMON/ITHICK/IPIPE(5),IPUMP(5),ITANK(3),IGASK(5),ITANK2(3)
24785 REAL IPIPE,IPUMP,ITANK,IGASK,ITANK2
24790 COMMON/THICKNS/PIPEI(5),PUMPI(5),GASKI(5)
24795 REAL PIPEI,PUMPI,GASKI
24800 COMMON/LOOPCT/NPI,NTK
24805 INTEGER NPI,NTK
24810 COMMON/IYRNO/IYRNUM
24815 INTEGER IYRNUM
24820 REAL WKDROP,WKPNDR,UFRAC,WKPPNDR
24825 COMMON/LINE/LINETIM(3)
24830 REAL LINETIM
24835 COMMON/CONNECT/WELDFLG,GASKET
24840 LOGICAL WELDFLG,GASKET
24845 COMMON/VLREM/TTREMVL,TPREMVL
24850 REAL TTREMVL,TPREMVL
24855 COMMON/TANKREP/TANKREP
24860 LOGICAL TANKREP
24865 REAL PMONRT
24870 COMMON/WATER/GWDPTH
24875 REAL GWDPTH
24880 COMMON/GEOL/POSZ,THETA,NFFLAG,POR,THETAP,PERM
24885 REAL POSZ,THETA,POR,THETAP,PERM
24890 REAL MOFRAC
24895 INTEGER FALNUM,FALNUM1,FALNUM3,FALNUM4,FALNUM7
24900 COMMON/FALNUM/FALNUM,FALNUM1(100),FALNUM2(100),FALNUM3(100),
24905+  FALNUM4(100),FALNUM5(100),FALNUM7(100)
24910 COMMON/FALNUM6/FALNUM6(100)
24915 CHARACTER FALNUM6*2,DLAB*2
24920 REAL FALNUM2,FALNUM5
24925 REAL DIFFI,DIFF1,DIFF2,VAPRESS,VAPWDIS
24930 COMMON/VAPWDIS/VAPWDIS(3)
24935 REAL PIDFSPH,PIRPSPH,PILKSPH,TKDFSPH,TKRPSPH,TKLKSPH,
24940+WLDFSPH,WLRPSPH,GKDFSPH,GKLKSPH,PMPSPH
24945 COMMON/SPHVOL/PIDFSPH(2),PIRPSPH(2),PILKSPH(2),TKDFSPH,
24950+TKRPSPH,TKLKSPH,WLDFSPH(2),WLRPSPH(2),GKDFSPH(2),GKLKSPH(2),
24955+PMPSPH(2)
24960 REAL VTIME
24965 COMMON/VTIME/VTIME(3)
24970 COMMON/VAPPRB/VAPSENS,VSENSOR
24975 REAL VAPSENS,VSENSOR
24980 COMMON/MASSDIF/DIFFI,DIFF1,DIFF2,VAPRESS
24985 REAL VOL1
24990 COMMON/THRESH/LOWER,FLASHTM,FLASHX,FLASHVL,POOF,FLASHDP,FLASHPT
24995 REAL FLASHPT,LOWER,FLASHTM,FLASHX,FLASHVL,POOF,FLASHDP
25000 REAL TFLASHX,TFLASHT
25005 COMMON/LOWVOL1/VOL1
25010 REAL TRP
25015 REAL TCLVOL,TTCVOL
25020 COMMON/CCLEAN/TCLVOL,TTCVOL
25025 REAL TRVOL
25030 COMMON/RCLEAN/TRVOL
25035 COMMON/EXCAVAT/TXLNGTH(3),TXWIDTH(3),TXDEPTH(3),PXLNGTH(5),
25040+     PXWIDTH(5),PXDEPTH(5)
25045 REAL TXDEPTH,PXDEPTH
25050 REAL PPNDPTH
25055 COMMON/CONTAM/PPNDPTH,TPNDPTH
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25060 COMMON/PIPETIM/PIPDEF(5),WLDDEF(5),GSKDEF(5),PIPLK(5),
25065+GSKLK(5),RUPPIP(5)
25070 COMMON/TANKTIM/TNKDEF(3),TNKLK(3),RUPTNK(3)
25075 COMMON/SURFTIM/LOOSE,HOSPORT,PMPLK(5),RUPWLD(5),VENT
25080 COMMON/CONT/UGCONT(3),AGCONT(3),PIPCONT(5),NUGCONT(3),NAGCONT(3)
25085+,NPICONT(5)
25090 COMMON/WALL/TK2WALL,PI2WALL
25095 INTEGER PIPDEF,WLDDEF,GSKDEF,PIPLK,GSKLK,RUPPIP
25100 INTEGER TNKDEF,TNKLK,RUPTNK
25105 INTEGER LOOSE,HOSPORT,PMPLK,RUPWLD,VENT
25110 INTEGER UGCONT,AGCONT,PIPCONT,NUGCONT,NAGCONT,NPICONT
25115 REAL RPSEAM(2)
25120 LOGICAL TK2WALL,PI2WALL
25125 COMMON/DAVOL1/LOSEVOL,OVERVOL(12),HOSEVOL,PMLKVOL(5),RPWLVOL(5)
25130 REAL LOSEVOL,OVERVOL,HOSEVOL,PMLKVOL,RPWLVOL
25135 COMMON/VOL2/ PIDEFVL(5),WLDEFVL(5),GKDEFVL(5),PILKVOL(5),GKLKVOL
25140+(5),RPPIVOL(5)
25145 REAL PIDEFVL,WLDEFVL,GKDEFVL,PILKVOL,GKLKVOL,RPPIVOL
25150 COMMON/VOL3/ TKDEFVL(3),TKLKVOL(3),RPTKVOL(3)
25155 REAL TKDEFVL,TKLKVOL,RPTKVOL
25160 COMMON/RATE1/ PIDEFRT(5),WLDEFRT(5),GKDEFRT(5),PILKRT(5),GKLKRT
25165+(5),RPPIRT(5)
25170 REAL PIDEFRT,WLDEFRT,GKDEFRT,PILKRT,GKLKRT,RPPIRT
25175 COMMON/RATE2/ TKDEFRT(3),TKLKRT(3),RPTKRT(3)
25180 COMMON/RATE3/ PMLKRT(5),RPWLRT(5)
25185 REAL TKDEFRT,TKLKRT,RPTKRT,PMLKRT,RPWLRT
25190
25195 COMMON/CATAST/CATASTR(12)
25200 REAL CATVOL
25205 INTEGER CATASTR
25210
25215 COMMON/CATAS/VANDAL,WIND,EARTHQU,FLOOD,FIREXPL,FIRE
25220 INTEGER VANDAL,WIND,EARTHQU,FLOOD,FIREXPL,FIRE
25225
25230 REAL MONREL,SURF,SUBSURF,QUARSUB,MOVOLUM
25235 COMMON/FRAC/AGFRAC,PAGFRAC,AGCONFR,UGCONFR
25240 REAL AGFRAC,PAGFRAC,AGCONFR,UGCONFR
25245 REAL SPILLRT,SPILL
25250 REAL RUPREL,LKREL,CATREL
25255
25260
25265 LOGICAL DETECT
25270 REAL DETTIME
25275 REAL AGSPILL,AGRUPT,UGRUPT,AGLEAK,UGLEAK
25280
25285 COMMON/FILL/FILLRT(5),FILLTIM(5),FILLFR(5),FILLVOL(5)
25290 REAL FILLRT,FILLTIM,FILLFR,FILLVOL
25295 REAL CONTVOL(5),FLOWRT(5)
25300 COMMON/DISCH/DISCRT(5),DISCTIM(5),DISCFR(5),VEHTANK,THRUPUT
25305 REAL DISCRT,DISCTIM,DISCFR,DISCVOL
25310 COMMON/DISCVOL/DISCVOL(5)
25315 REAL VEHTANK
25320
25325 COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
25330
25335 LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
25340
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25345 REAL TSURF,TSUB,TTOTAL
25350 COMMON/UNDET/TSUB,TSURF,SUBSURF,SURF
25355 REAL LKRATE
25360
25365 COMMON/MONIT/MONMETH(7),PIPMON
25370 LOGICAL MONMETH,PIPMON
25375 COMMON/INVCNTL/INVCNTL
25380 LOGICAL INVCNTL
25385
25390 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
25395
25400 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPUMP,AGPIPE
25405
25410 COMMON/TIMCONV/HRSMO,MINMO,DAYMO
25415
25420 REAL HRSMO,MINMO,DAYMO
25425
25430 LOGICAL PIREPAR,TKREPAR,PMREPAR
25435 COMMON/PITRE/PIREPAR(5),TKREPAR(3),PMREPAR(5)
25440 REAL DEFREL
25445
25450 COMMON/INVEN/MINVLIM,IINVLIM,WINVLIM
25455
25460 REAL MINVLIM,IINVLIM,WINVLIM
25465
25470 COMMON/PRINSP/PIPINSF(2),TNKINSF(2),PMPINSF(2),SECINSP(2)
25475 REAL PIPINSF,TNKINSF,PMPINSF,SECINSP
25480
25485 COMMON/TSTFLAG/TKTSTG,PITSTG,ULTRTST
25490 LOGICAL TKTSTG,PITSTG,ULTRTST,PIPSTST,TNKSTST
25495 COMMON/TPLIMIT/PITSLIM,TKTSLIM,PIMNLIM
25500 REAL PITSLIM,TKTSLIM,PIMNLIM
25505 COMMON/SEMITST/TNKSTST,PIPSTST
25510
25515 COMMON/TSTMON/PITEST,TKTEST,ULTEST,LYSTEST
25520 INTEGER PITEST,TKTEST,ULTEST,LYSTEST
25525 COMMON/MCGDROP/MCWHORT,GDROP
25530 REAL MCWHORT,GDROP
25535 REAL PMOPEN,TMOPEN
25540 COMMON/MONTHLY/PMOPEN,TMOPEN
25545 REAL LYSIM,LYSDPTH,PLYSIM,TPNDPTH
25550 COMMON/LYS/LYSIM(2),LYSDPTH,PLYSIM
25555
25560 REAL TKTHICK,TANK2
25565
25570 LOGICAL AG2DET,UG2DET,PI2DET
25575 COMMON/ALARM/INTERST(5,2),INTER,PIINTER(5,2),PINTER
25580 REAL INTERST,INTER,PIINTER,PINTER
25585 COMMON/INSP/INSPECT(4)
25590 LOGICAL INSPECT
25595 COMMON/TKINFO/FRACTUG,TNKCAP(3)
25600 REAL FRACTUG,TNKCAP
25605 REAL PIPLEN
25610 COMMON/PIPEDM/PIPLEN(5)
25615 REAL FNU,FNB
25620 LOGICAL ONGO
25625 REAL DM,WD,LN
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25630 COMMON/CDIAM/PIDFDIA(5),PILKDIA(5),PMLKDIA(5),GKLKDIA(5),TKLKDIA
25635+(3)
25640 REAL PIDFDIA,PILKDIA,PMLKDIA,GKLKDIA,TKLKDIA
25645 COMMON/CWID/PIDFWID(5),RPPIWID(5),TKDFWID(3),RPTKWID(3),WLDFWID
25650+(5),GKDFWID(5),RPWLWID(5)
25655 REAL PIDFWID,RPPIWID,TKDFWID,RPTKWID,WLDFWID,
25660+GKDFWID,RPWLWID
25665 COMMON/CLEN/PIDFLEN(5),RPPILEN(5),TKDFLEN(3),RPTKLEN(3),WLDFLEN
25670+(3),GKDFLEN(5),RPWLLEN(5)
25675 REAL PIDFLEN,RPPILEN,TKDFLEN,RPTKLEN,WLDFLEN,
25680+GKDFLEN,RPWLLEN
25685 COMMON/WSTCON/SGRAV
25690 REAL SGRAV
25695 COMMON/PRESS/PRESS(5,5)
25700 REAL PRESS
25705 COMMON/RUPLEN/CLENGTH(5),CWIDTH(5),CDIAM(5)
25710 REAL CLENGTH,CWIDTH,CDIAM
25715 COMMON/SEAM/SEAMLEN,SEAMWID
25720 REAL SEAMLEN,SEAMWID
25725 COMMON/STRESS/STRESS(5),CORTHDS(2)
25730 COMMON/DIAM/PDIAM(5)
25735 REAL PDIAM
25740 COMMON/MATL/TNKMATL,PIPMATL
25745 REAL STRESS,CORTHDS
25750 INTEGER TNKMATL,PIPMATL
25755 COMMON/OPHRS/OPHRSDY
25760 REAL OPHRSDY
25765 COMMON/SUFTIM/HOSPERM,DRANPMP(5)
25770 INTEGER HOSPERM,DRANPMP
25775 COMMON/SOILCH/SPHER,VOID,DPART
25780 REAL SPHER,VOID,DPART
25785 COMMON/CHARAC/DENS,VISCOS
25790 REAL DENS,VISCOS
25795 REAL TLENGTH,TWIDTH,THEIGHT,UGTHGHT,AGTHGHT,DIAM,LENGTH
25800 COMMON/TANKDM/TLENGTH(3),TWIDTH(3),THEIGHT(3),UGTHGHT(3),
25805+AGTHGHT(3),DIAM(3),LENGTH(3)
25810 COMMON/COUNT/NPIPDEF(5),NWLDDEF(5),NGSKDEF(5),NPIPLK(5),NGSKLK(5),
25815+NRUPPIP(5),NPMPLK(5),NRUPWLD(5),NTNKLK(3),NTNKDEF(3),NRUPTNK(3)
25820 REAL NPIPDEF,NWLDDEF,NGSKDEF,NPIPLK,NGSKLK,NRUPPIP,NPMPLK,NRUPWLD,
25825+     NTNKLK,NTNKDEF,NRUPTNK
25830 INTEGER YR,YRO,K
25835 COMMON/VOLTOT/TVOLUME
25840 REAL TVOLUME
25845 REAL MREL
25850 COMMON/CORE/PCORE(5),GCORE(5),PMCORE(5),TCORE(3),TCORE2(3)
25855 COMMON/CORE1/PCORE2(5),PIEXT2(5),PIEXLO2(5)
25860 REAL PCORE2,PIEXT2,PIEXLO2
25865 REAL PCORE,GCORE,PMCORE,TCORE,TCORE2
25870 COMMON/ECORE/PIEXT(5),TKEXT(3),PMEXT(5),TKEXT2(3)
25875 REAL PIEXT,TKEXT,PMEXT,TKEXT2
25880 COMMON/LIN/LINER
25885 LOGICAL LINER
25890 COMMON/TKCONT/CONCPAD,ASPHPAD
25895 LOGICAL CONCPAD,ASPHPAD
25900 LOGICAL TREMREP,PREMREP
25905 COMMON/REMREPS/TREMREP,PREMREP
25910C
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25915 INTEGER PTSTFRQ,TTSTFRQ,UTSTFRQ,LTSTFRQ
25920 COMMON/FREQ/PTSTFRQ,TTSTFRQ,UTSTFRQ,LTSTFRQ
25925C
25930 COMMON/FLSHPT/FLASHON,FLREMED
25935 LOGICAL FLASHON,FLREMED
25940 REAL PREMDT,PREMRT,TREMDT,TREMRT,REMVL
25945 REAL PIVOL(5),GKVOL(5),WLVOL(5),PMVOL(5),TKVOL(3)
25950 REAL PRPIVOL(5),PRGKVOL(5),PRWLVOL(5),PRPMVOL(5),PRTKVOL(3)
25955 COMMON/DEFFLAG/DLTNK(3),DDTNK(3),DRTNK(3),DLGSK(5),DDGSK(5),
25960+DDWLD(5),DRWLD(5),DLPIP(5),DRPIP(5),DDPIP(5),DLPMP(5),DALL
25965 LOGICAL DLTNK,DDTNK,DRTNK,DLGSK,DDGSK,DDWLD,DRWLD,DLPIP,DRPIP,
25970+DDPIP,DLPMP,DALL
25975 REAL TPRSURF,TPRSUB,PRSUB,PRSURF
25980 COMMON/BYPASS/WLDFLGR,WLDFLGD,GSKFLGL,GSKFLGD
25985 LOGICAL WLDFLGR,WLDFLGD,GSKFLGL,GSKFLGD
25990 COMMON/NYR/NYEAR
25995 INTEGER NYEAR
26000 INTEGER QTR
26005 COMMON/ISEED/ISEED
26010 INTEGER ISEED
26015 REAL CI
26020 COMMON/INV/MONINV,WEEKINV
26025 LOGICAL MONINV,WEEKINV
26030 LOGICAL SKIP,MSKIP
26035 COMMON/VAPOR/TKDFVAP,TKRPVAP,TKLKVAP,PIDFVAP(5),PIRPVAP(5),
26040+ PILKVAP(5),WGDFVAP(5),WGLRVAP(5),PMPVAP(5)
26045 REAL TKDFVAP,TKRPVAP,TKLKVAP,PIDFVAP,PIRPVAP,PILKVAP,
26050+    WGDFVAP,WGLRVAP,PMPVAP
26055 COMMON/VFLAG/VAPFLG,VAPDET
26060 LOGICAL VAPFLG,VAPDET
26065 INTEGER NONLEAK,AGGFAIL,AGNYFAL,AGCORNO,AGFLASH,AGTKREP,AGPL15
26070 INTEGER AGUNDET,AGPLUME,AGPIPNO
26075 REAL CUMREL,AGPLVOL,AGPLARE,AGUNSAT
26080+,AGTK1ST
26085 COMMON/AGG/NONLEAK,AGGFAIL,AGNYFAL,AGCORNO,CUMREL,AGPIPNO,
26090+AGTKREP,AGPLUME,
26095+AGPLVOL,AGPLARE,AGUNSAT,AGPL15,AGUNDET,AGTK1ST
26100+,AGFLASH
26105 DIMENSION TVOLUME(40)
26110 DIMENSION AGUNDET(40),AGTK1ST(500)
26115 DIMENSION PTSTFRQ(40),TTSTFRQ(40),UTSTFRQ(5)
26120 DIMENSION TRP(40)
26125 DATA(CLENGTH(I),I=1,5)/10.,0.,36.,15.7,15.7/
26130 DATA(CWIDTH(I),I=1,5)/.25,0.,3.,.125,.125/
26135 DATA SEAMLEN/60./
26140 DATA SEAMWID/.0625/
26145 DATA(CORTHDS(I),I=1,2)/.25,.125/
26150 IF(DISTILL)THEN
26155    DRANPMP(2)=0
26160    PMPLK(2)=0
26165 ENDIF
26170 TKTEST=0
26175 ULTEST=0
26180 PITEST=0
26185 LYSTEST=0
26190  IF(YRO.EQ.O.OR.IYRNUM.LT.YRO)THEN
26195    YR=IYRNUM
```

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26200 ELSE
26205   YR=IYRNUM-YRO+1
26210 ENDIF
26215* SET THE TESTING FREQUENCIES.
26220 IF (TKTSTG) THEN
26225  IF(YRO.EQ.0)THEN
26230    DO 143 M=1,NYEAR
26235       IF (TTSTFRQ(M).EQ.IYRNUM) THEN
26240          TKTEST=12
26245          GO TO 144
26250       ENDIF
26255    143 CONTINUE
26260    144 CONTINUE
26265  ELSE
26270    DO 271 M=1,NYEAR
26275       IF (TTSTFRQ(M).EQ.(IYRNUM-YRO+1))THEN
26280          TKTEST=12
26285          GO TO 272
26290       ENDIF
26295    271 CONTINUE
26300    272 CONTINUE
26305   ENDIF
26310 ENDIF
26315 IF (PITSTG) THEN
26320    DO 943 M=1,NYEAR
26325       IF (PTSTFRQ(M).EQ.YR) THEN
26330          PITEST=12
26335          GO TO 944
26340       ENDIF
26345    943 CONTINUE
26350    944 CONTINUE
26355 ENDIF
26360 IF (ULTRTST) THEN
26365    DO 109 II=1,5
26370    IF (UTSTFRQ(II).EQ.YR) THEN
26375       ULTEST=12
26380       GOTO 431
26385    ENDIF
26390    109 CONTINUE
26395    431 CONTINUE
26400 ENDIF
26405 IF (MONMETH(4)) THEN
26410    IF (LTSTFRQ.EQ.3)LYSTEST=12
26415 ENDIF
26420 MREL=0
26425 IF(YR.EQ.1)THEN
26430*   INITIALIZATIONS
26435 SURF=0
26440 SUBSURF=0
26445 POOF=FLASHTM
26450 FLASHVL=0
26455 TSUB=0
26460 TSURF=0
26465 ENDIF
26470 QUARSUB=0
26475
26480 UGRUPT=0
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26485 AGRUPT=0
26490 AGSPILL=0
26495 AGLEAK=0
26500 UGLEAK=0
26505
26510 LKRATE=0.
26515 AGFRAC=0.
26520 AG2DET=.FALSE.
26525 UG2DET=.FALSE.
26530 PI2DET=.FALSE.
26535  IF(BATCH.AND.STORAGE)DISCVOL(2)=VEHTANK
26540 CONTVOL(1)=FILLVOL(1)
26545 FLOWRT(1)=FILLRT(1)
26550 DO 9683 L=2,NPI
26555 FLOWRT(L)=DISCRT(L)
26560 CONTVOL(L)=DISCVOL(L)
26565 9683 CONTINUE
26570 AGSP=0
26575 DO 83 L=1,NPI
26580     IF(L.LE.3)TKVOL(L)=0
26585     PIVOL(L)=0
26590     GKVOL(L)=0
26595     WLVOL(L)=0
26600     PMVOL(L)=0
26605 83 CONTINUE
26610************TO AVOID LEAKS WITH NO RELEASE**********************
26615 IF(UGTANK.AND.STORAGE)THEN
26620    RUPWLD(2)=0
26625    WLDDEF(2)=0
26630    GSKLK(2)=0
26635    GSKDEF(2)=0
26640 ENDIF
26645 IF(.NOT.GASKET)THEN
26650     DO 589 LP=1,NPI
26655         GSKDEF(LP)=0
26660         GSKLK(LP)=0
26665     589 CONTINUE
26670  ENDIF
26675**************************************
26680*    SET TIME OF FAILURE EQUAL TO MONTH ONE
26685*    IF IT IS A CONTINUEING LEAK.
26690  DO 403 L=1,NPI
26695     IF(NPIPDEF(L).EQ.1)  PIPDEF(L)=NPIPDEF(L)
26700     IF(NWLDDEF(L).EQ.1)  WLDDEF(L)=NWLDDEF(L)
26705    IF(NGSKDEF(L).EQ.1)    GSKDEF(L)=NGSKDEF(L)
26710     IF(NPIPLK(L).EQ.1)  PIPLK(L)=NPIPLK(L)
26715     IF(NGSKLK(L).EQ.1)   GSKLK(L)=NGSKLK(L)
26720     IF(NRUPPIP(L).EQ.1)RUPPIP(L)=NRUPPIP(L)
26725     IF(NPMPLK(L).EQ.1)  PMPLK(L)=NPMPLK(L)
26730     IF(NRUPWLD(L).EQ.1)     RUPWLD(L)=NRUPWLD(L)
26735 IF(NPICONT(L).EQ.1)  PIPCONT(L)=NPICONT(L)
26740 403 CONTINUE
26745 DO 4030 L=1,NTK
26750 IF(NTNKLK(L).EQ.1)  TNKLK(L)=NTNKLK(L)
26755 IF(NTNKDEF(L).EQ.1)  TNKDEF(L)=NTNKDEF(L)
26760 IF(NRUPTNK(L).EQ.1)  RUPTNK(L)=NRUPTNK(L)
26765 IF(NAGCONT(L).EQ.1)  AGCONT(L)=NAGCONT(L)
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IF(NUGCONT(L).EQ.1) UGCONT(L)=NUGCONT(L)
4030 CONTINUE
*  MONTH LOOP
DO 50 K=1,12
    ISEED=ISEED+K
    CALL RANSET(ISEED)
*   INITIALIZATIONS
    MOFRAC=1.0
IF(MOD(K,MINT).EQ.0)THEN
    MINVLIM=MINV
ELSE
    MINVLIM=1000000.
ENDIF
TREMDT=0
TREMRT=0
PREMRT=0
PREMDT=0
TMOPEN=0
DETTIME=0
DETECT=.FALSE.
VAPDET=.FALSE.
TREMREP=.FALSE.
PREMREP=.FALSE.
MONREL=0.
LKREL=0.
DEFREL=0.
RUPREL=0.
CATVOL=0.
TPRSURF=TSURF
PRSURF=SURF
PRSUB=SUBSURF
TPRSUB=TSUB
DO 30689 L=1,NPI
PRPIVOL(L)=PIVOL(L)
PRPMVOL(L)=PMVOL(L)
PRWLVOL(L)=WLVOL(L)
PRGKVOL(L)=GKVOL(L)
IF(L.LE.3)PRTKVOL(L)=TKVOL(L)
30689 CONTINUE
SPILL=0
DO 80776 L=1,NPI
IF(L.LE.NTK)TKREPAR(L)=.FALSE.
PMREPAR(L)=.FALSE.
PIREPAR(L)=.FALSE.
80776 CONTINUE
*   SET TESTING DATES
IF(TNKSTST) THEN
  TKTEST=6
  IF(K.EQ.12)TKTEST=12
ENDIF
IF(PIPSTST) THEN
  PITEST=6
  IF(K.EQ.12)PITEST=12
ENDIF
IF(PIPMON)PITEST=K
IF (MONMETH(4)) THEN
    IF ((LTSTFRQ.EQ.1).OR.(LTSTFRQ.EQ.4))LYSTEST=K
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27055    IF  (LTSTFRQ.EQ.2) THEN
27060        IF((MOD(K,3)).EQ.0)  THEN
27065           LYSTEST=K
27070        ENDIF
27075    ENDIF
27080 ENDIF
27085* CATASTROPHIC FAILURES
27090 IF(CATASTR(K).EQ.K)THEN
27095       ITYPFLG=2060
27100       DLAB='CA'
27105           FALNUM=FALNUM+1
27110          FALNUM1(FALNUM)=ITYPFLG
27115          FALNUM7(FALNUM)=(YR-1)*12+K
27120    VOLTMP=0.
27125    IF(STORAGE)THEN
27130        VOLTMP=0.5*TNKCAP(1)
27135    ELSE
27140        DO 29834 L=1,NTK
27145              VOLTMP=VOLTMP+0.8*TNKCAP(L)
27150          29834 CONTINUE
27155    ENDIF
27160    IF(WIND.EQ.K)CATVOL=VOLTMP+CATVOL
27165    IF(EARTHQU.EQ.K)CATVOL=VOLTMP+CATVOL
27170    IF(FLOOD.EQ.K)CATVOL=VOLTMP+CATVOL
27175    IF(FIREXPL.EQ.K)CATVOL=VOLTMP+CATVOL
27180    IF(FIRE.EQ.K)CATVOL=VOLTMP+CATVOL
27185   IF(VANDAL.EQ.K)THEN
27190*   NO REPLACEMENT
27195   IF(AGTANK)THEN
27200      IF(AGCONT(1).EQ.K)THEN
27205         SURF=AGCONFR*VOLTMP+SURF
27210         SUBSURF=(1-AGCONFR)*VOLTMP+SUBSURF
27215        ELSE
27220         SURF=VOLTMP+SURF
27225      ENDIF
27230     ELSEIF(IGTANK)THEN
27235       IF(UGCONT(1).EQ.K)THEN
27240          SURF=UGCONFR*VOLTMP+SURF
27245          SUBSURF=(1-UGCONFR)*VOLTMP+SUBSURF
27250       ELSE
27255          SURF=VOLTMP+SURF
27260       ENDIF
27265     ELSE
27270*     UGTANK
27275***
27280***
27285   ENDIF
27290  ENDIF
27295   IF(((WIND.EQ.K).AND.(AGTANK.OR.IGTANK)).OR.(EARTHQU.EQ.K).OR.
27300+    ((FLOOD.EQ.K).AND.(AGTANK.OR.IGTANK)).OR.(FIREXPL.EQ.K).OR.(
27305+FIRE.EQ.K))THEN
27310*        REPLACE EVERYTHING
27315     DO 31 L=1,NPI
27320       PIPCONT(L)=0
27325      IF(.NOT.PIPSEC) PIPCONT(L)=K
27330           NPICONT(L)=0
27335         PIREPAR(L)=.TRUE.
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         PMREPAR(L)=.TRUE.
     IF(WLDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,7)
        IF(RPWLVOL(L).GT.0)  CALL FIX(DLAB,K,YR,L,10)
     IF(PIDEFVL(L).GT.0)  THEN
      INTLK(L)=0
       CALL FIX(DLAB,K,YR,L,6)
      PIPAGE(L)=0
      NUMLK(L)=0
      PRAN(L)=FNU(0.,2.)
       ENDIF
     IF(L.LE.NTK)THEN
           AGCONT(L)=0
           UGCONT(L)=0
      IF  (NOSECON)  THEN
          AGCONT(L)=K
          UGCONT(L)=K
      ENDIF
   IF(RETROFT)UGCONT(L)=K
           NAGCONT(L)=0
           NUGCONT(L)=0
         TKREPAR(L)=.TRUE.
     IF(TKDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,3)
      ENDIF
     IF(GKDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,8)
      IF(L.LE.NTK)  THEN
        IF(RPTKVOL(L).GT.0)  CALL FIX(DLAB,K,YR,L,2)
      ENDIF
        IF(RPPIVOL(L).GT.0)  THEN
      INTLK(L)=0
        CALL FIX(DLAB,K,YR,L,5)
      PIPAGE(L)=0
      NUMLK(L)=0
      PRAN(L)=FNU(0.,2.)
                 ENDIF
        CALL FIX(DLAB,K,YR,L,4)
      INTLK(L)=0
      PIPAGE(L)=0
      NUMLK(L)=0
      PRAN(L)=FNU(0.,2.)
           PMPLK(L)=0
           CALL FIX(DLAB,K,YR,L,9)
    PMPVAP(L)=0
      CALL VAPZERO(3,L)
      CALL VAPZERO(1,L)
            PMLKRT(L)=0
      IF(L.LE.NTK)CALL FIX(DLAB,K,YR,L,1)
           PMLKVOL(L)=0
     31 CONTINUE
*     RESAMPLE TIME TO FAILURE
        CALL REPLAC(8,1)
VAPSENS=VSENSOR
            IJ=FALNUM
       FALNUM6(IJ)='CA'
        DETTIME=DETTIME+2880
        IF  (((MAX(DETTIME,TREMDT))-TREMDT).NE.0)  THEN
           TREMDT=DETTIME
           TREMRT=CATVOL/DETTIME
         ENDIF
             FALNUM2(IJ)=FALNUM2(IJ)+CATVOL
             FALNUM5(IJ)=FALNUM5(IJ)+DETTIME/60.
           FALNUM3(IJ)=((YR-1)*12)+K
        IF(YRO.NE.O.AND.IYRNUM.LT.YRO)TANKREP=.TRUE.
         TREMREP=.TRUE.
          DALL=.TRUE.
       IF(AGTANK)THEN
          SURF=SURF+AGFRAC*CATVOL
          SUBSURF=(1-AGFRAC)*CATVOL+SUBSURF
         ELSEIF(IGTANK)THEN
        SUBSURF=CATVOL+SUBSURF
***
         ELSE
          SUBSURF=CATVOL+SUBSURF
        ENDIF
  ENDIF
VANDAL=0
WIND=0
EARTHQU=0
FLOOD=0
FIREXPL=0
FIRE=0
*CATASTR IS ZEROED OUT AFTER CONTAINMENT FAILURE CHECK FOR REMEDL
  TREMREP=.TRUE.
  MONREL=MONREL+CATVOL
ENDIF
*   LOOSE HOSE CONNECTIONS
  IF(LOOSE.EQ.K)THEN
      FALNUM=FALNUM+1
      FALNUM1(FALNUM)=4070+NTK
      FALNUM3(FALNUM)=(YR-1)*12+K
      FALNUM7(FALNUM)=(YR-1)*12+K
     SPILLRT=FNU(0.,DISCRT(NPI))
  TMIN=1.
 T1=.25*DISCTIM(NPI)
 T2=DISCTIM(NPI)
     CALL RATEDET(SPILLRT,TMIN,T1,T2,DETECT,DETTIME)
    IF(DETECT)THEN
      FALNUM6(FALNUM)='RD'
        SPILL=SPILLRT*DETTIME
         AGSP=AGSP+SPILL
      IF(AGCONT(NTK).EQ.K)THEN
      FALNUM4(FALNUM)=1
             TEMP=TSURF+SURF+AGCONFR*SPILL
        SUBSURF=SUBSURF+(1-AGCONFR)*SPILL
        MONREL=MONREL+SPILL
     ELSE
        TEMP=TSURF+SURF+SPILL
        SPILL=0
       FALNUM4(FALNUM)=0
     ENDIF
       CALL CLENUP(TEMP)
    TSURF=0
    SURF=0
  TPRSURF=0
  PRSURF=0
```

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          FALNUM2(FALNUM)=SPILLRT*DETTIME
          FALNUM5(FALNUM)=DETTIME/60.
        ELSE
          FALNUM5(FALNUM)=DISCTIM(NPI)/60.
          FALNUM2(FALNUM)=SPILLRT*DISCTIM(NPI)
         SPILL=SPILLRT*DISCTIM(NPI)
          IF(AGCONT(NTK).EQ.K)THEN
        FALNUM4(FALNUM)=1
             TSURF=TSURF+AGCONFR*SPILL
             TSUB=TSUB+(1-AGCONFR)*SPILL
          ELSE
             TSURF=TSURF+SPILL
          FALNUM4(FALNUM)=0
          ENDIF
         AGSP=AGSP+SPILL
      ENDIF
      AGSPILL=SPILL+AGSPILL
      LOOSE=0
  ENDIF
*  OVERFLOWS
DO 76599 L=1,NTK
CALL OVERFLW(L,OFLOW)
  IF(OFLOW.EQ.1)THEN
       FALNUM=FALNUM+1
       FALNUM1(FALNUM)=4080+L
       FALNUM3(FALNUM)=(YR-1)*12+K
       FALNUM4(FALNUM)=0
       FALNUM7(FALNUM)=(YR-1)*12+K
        FALNUM6(FALNUM)='RD'
   IF(AGTANK.OR.IGTANK)THEN
     SPILLRT=FILLRT(L)
     IF(BATCH)THEN
     DETTIME=FNU(0.,FILLTIM(L))
      ELSE
      DETTIME=FNU(0.,30.)
      ENDIF
     SPILL=SPILLRT*DETTIME
        AGSP=AGSP+SPILL
     SPILL=(1-AGCONFR)*SPILL
     IF(ULVAULT.OR.LVAULT)THEN
          IF(UGCONT(L).EQ.K)THEN
       FALNUM4(FALNUM)=1
            TSURF=UGCONFR*SPILL+TSURF
            TSUB=(1-UGCONFR)*SPILL+TSUB
           ELSE
            TSURF=SPILL+TSURF
         ENDIF
       ELSE
          IF(AGCONT(L).EQ.K)THEN
       FALNUM4(FALNUM)=1
             SURF=SURF+AGCONFR*SPILL
             TSUB=TSUB+(1-AGCONFR)*SPILL
             TEMP=TSURF+SURF
           ELSE
             TEMP=TSURF+SURF+SPILL
             SPILL=0
            SURF=SURF+SPILL
         ENDIF
        MONREL=SPILL+MONREL
        AGSPILL=SPILL+AGSPILL
    ENDIF
          TEMP=TSURF+SURF+AGCONFR*SPILL
    CALL CLENUP (TEMP)
    TSURF=0
    SURF=0
 TPRSURF=0
 PRSURF=0
     FALNUM2 (FALNUM) =SPILLRT*DETTIME
     FALNUM5 (FALNUM) =DETTIME/60.
  ELSEIF (VAULT) THEN
SPILL=MIN (FNU (15.,FILLVOL (L)), (15.+FILLRT (L) *FNU (1.,5.)))
     FALNUM2 (FALNUM) =SPILL
     FALNUM5 (FALNUM) =1
       AGSP=AGSP+SPILL
    IF (UGCONT (L) .EQ.K) THEN
      FALNUM4 (FALNUM) =1
           TEMP=TSURF+SURF
    ELSE
        TEMP=TSURF+SURF+SPILL
        SPILL=0
    ENDIF
    CALL CLENUP (TEMP)
   TSURF=0
   SURF=0
 TPRSURF=0
 PRSURF=0
    TEMP=0
    IF (UGCONT (L) .EQ.K) THEN
     FALNUM4 (FALNUM) =1
       TSURF=TSURF+UGCONFR*SPILL
       TSUB= (1-UGCONFR) *SPILL+TSUB
      ELSE
        TSURF=TSURF+SPILL
    ENDIF
 ELSE
    IF ((RUPWLD (2) .EQ.K) .OR. (GSKDEF (2) .EQ.K) .OR. (WLDDEF (2) .EQ.K)
        .OR. (GSKLK (2) .EQ.K) .OR. (VENT.EQ.K)) THEN
        SPILL=3.3
    ENDIF
    IF ((RUPWLD (2) .EQ.K) .OR. (GSKDEF (2) .EQ.K) .OR. (WLDDEF (2) .EQ.K)
        .OR. (GSKLK (2) .EQ.K)) THEN
         TSUB=SPILL+TSUB
    FALNUM2 (FALNUM) =SPILL
    FALNUM5 (FALNUM) =1
      ELSEIF (VENT.EQ.K) THEN
       TSUB=SPILL+TSUB
    FALNUM2 (FALNUM) =SPILL
    FALNUM5 (FALNUM) =1
      ELSE
       NO OVERFLOW PATHWAY
       FALNUM1 (FALNUM) =0
       FALNUM2 (FALNUM) =0
       FALNUM3 (FALNUM) =0
       FALNUM4 (FALNUM) =0
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          FALNUM5 (FALNUM) =0
          FALNUM6 (FALNUM) ='ND'
          FALNUM7 (FALNUM) =0
          FALNUM=FALNUM-1
       ENDIF
       ENDIF
 SPILL=0
   ENDIF
 76599 CONTINUE
*  PORTABLE HOSE RUPTURE
   IF (HOSPORT.EQ.K) THEN
       FALNUM=FALNUM+1
       FALNUM1 (FALNUM) =4090+NTK
       FALNUM3 (FALNUM) = (YR-1) *12+K
       FALNUM4 (FALNUM) =0
       FALNUM7 (FALNUM) = (YR-1) *12+K
 SPILLRT=FNU (0.,DISCRT (NPI))
       TMIN=1.
      T1=.25*DISCTIM (NPI)
      T2=DISCTIM (NPI)
     CALL RATEDET (SPILLRT,TMIN,T1,T2,DETECT,DETTIME)
       FALNUM2 (FALNUM) =SPILLRT*DETTIME
       FALNUM5 (FALNUM) =DETTIME/60.
      IF (DETECT) THEN
        FALNUM6 (FALNUM) ='RD'
      SPILL=SPILLRT*DETTIME
         AGSP=AGSP+SPILL
       IF (AGCONT (NTK) .EQ.K) THEN
        FALNUM4 (FALNUM) =1
             TEMP=TSURF+SURF+AGCONFR*SPILL
          SUBSURF=SUBSURF+ (1-AGCONFR) *SPILL
       ELSE
          TEMP=TSURF+SURF+SPILL
       ENDIF
      CALL CLENUP (TEMP)
      TSURF=0
      SURF=0
    TPRSURF=0
    PRSURF=0
      SPILL= (1-AGCONFR) *SPILL
      ELSE
      SPILL=SPILLRT*FNU (0.,DISCTIM (NPI))
       AGSP=AGSP+SPILL
       IF (AGCONT (NTK) .EQ.K) THEN
        FALNUM4 (FALNUM) =1
          TSURF=TSURF+AGCONFR*SPILL
          TSUB=TSUB+ (1-AGCONFR) *SPILL
       ELSE
          TSURF=TSURF+SPILL
       ENDIF
      ENDIF
      AGSPILL=SPILL+AGSPILL
      MONREL=SPILL+MONREL
      HOSPORT=0
    SPILL=0
   ENDIF
*    PERMANENT HOSE RUPTURE
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28765    IF (HOSPERM.EQ.K) THEN
28770        FALNUM=FALNUM+1
28775        FALNUM1 (FALNUM) =4100+NTK
28780        FALNUM3 (FALNUM) = (YR-1) *12+K
28785        FALNUM4 (FALNUM) =0
28790        FALNUM7 (FALNUM) = (YR-1) *12+K
28795 SPILLRT=FNU (0.,DISCRT (NPI))
28800        TMIN=.25
28805      T1=.25
28810      T2=1.4
28815     CALL RATEDET (SPILLRT,TMIN,T1,T2,DETECT,DETTIME)
28820       FALNUM2 (FALNUM) =SPILLRT*DETTIME
28825       FALNUM5 (FALNUM) =DETTIME/60.
28830      IF (DETECT) THEN
28835      SPILL=SPILLRT*DETTIME
28840         AGSP=AGSP+SPILL
28845       IF (AGCONT (NTK) .EQ.K) THEN
28850        FALNUM6 (FALNUM) ='RD'
28855              TEMP=TSURF+SURF+AGCONFR*SPILL
28860       SUBSURF=SUBSURF+ (1-AGCONFR) *SPILL
28865       MONREL=MONREL+SPILL
28870       ELSE
28875       TEMP=TSURF+SURF+SPILL
28880       ENDIF
28885     CALL CLENUP (TEMP)
28890     TSURF=0
28895     SURF=0
28900   TPRSURF=0
28905   PRSURF=0
28910     ELSE
28915     SPILL=SPILLRT*FNU (0.,DISCTIM (NPI))
28920      AGSP=AGSP+SPILL
28925     ENDIF
28930     AGSPILL=SPILL+AGSPILL
28935     HOSPERM=0
28940   SPILL=0
28945  ENDIF
28950 IF (AGPUMP) THEN
28955*   PUMP DRAIN LEFT OPEN
28960 DO 19643 L=1,NPI
28965   IF (DRANPMP (L) .EQ.K) THEN
28970      FALNUM=FALNUM+1
28975      FALNUM1 (FALNUM) =4110+L
28980      FALNUM3 (FALNUM) = (YR-1) *12+K
28985      FALNUM7 (FALNUM) = (YR-1) *12+K
28990      FALNUM4 (FALNUM) =0
28995      SPILL=DISCRT (L) *FNU (1.,3.)
29000      FALNUM2 (FALNUM) =SPILL
29005      FALNUM5 (FALNUM) =1
29010       FALNUM6 (FALNUM) ='RD'
29015        AGSP=AGSP+SPILL
29020     IF (PIPCONT (L) .EQ.K) THEN
29025           TEMP=TSURF+SURF+PAGFRAC*SPILL
29030     SUBSURF=SUBSURF+ (1-PAGFRAC) *SPILL
29035     MONREL=MONREL+SPILL
29040    ELSE
29045     TEMP=TSURF+SURF+SPILL
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      SPILL=0
       ENDIF
       CALL CLENUP(TEMP)
      TSURF=0
      SURF=0
    TPRSURF=0
    PRSURF=0
       SPILL=(1-PAGFRAC)*SPILL
       AGSPILL=SPILL+AGSPILL
       DRANPMP(L)=0
       SPILL=0
    ENDIF
 19643 CONTINUE
 ENDIF
 AGSPILL=0
 TEMP=0
*   PIPE INSTALLATION DEFICEINCY.
   DO 51 L=1,NPI
      IF(PIPDEF(L).EQ.K)THEN
      ITYPFLG=1010+L
***NOT A CONTINUOUS LEAK
         IF(PIDEFVL(L).EQ.0)THEN
         FALNUM=FALNUM+1
         FALNUM1(FALNUM)=ITYPFLG
         FALNUM7(FALNUM)=(YR-1)*12+K
             ONGO=.FALSE.
       CALL LEAKRT(ONGO,1,L,0,LKRATE,DM,PIDFWID(L),PIDFLEN(L))
          PIDEFRT(L)=LKRATE
         ENDIF
 DETECT=.FALSE.
 IF(MONMETH(7).AND.PIPSEC)THEN
    DLAB='IS'
* INTERSTITIAL MONITORING
    PIINTER(L,2)=FNB(PIINTER(L,1))
    IF(PIINTER(L,2).EQ.0)THEN
       DETTIME=FNU(60.,720.)
       DETECT=.TRUE.
       GO TO 1
    ENDIF
 ENDIF
         DETECT=.FALSE.
         IF(AGPIPE)THEN
             TMIN=.25
             IF(BATCH)T2=CONTVOL(L)/FLOWRT(L)
       IF(CONT)THEN
          T2=(24-OPHRSDY)*60.
          IF(T2.LT.(4.*60.))T2=4.*60.
        ENDIF
             T1=.25*T2
           CALL RATEDET(PIDEFRT(L),TMIN,T1,T2,DETECT,DETTIME)
           DLAB='RD'
            IF(DETECT) GO TO 1
            IF(INVCNTL)THEN
            CALL IMMINV(1,L,PIDEFRT(L),DETECT,DETTIME)
            DLAB='II'
            IF(DETECT) GO TO 1
            ENDIF
        IF(MONMETH(5))THEN
          DLAB='VW'
           IF((PIPCONT(L).EQ.K).OR.(.NOT.PIPSEC))THEN
            IF(.NOT.VAPFLG)THEN
            IF(PIDFVAP(L).EQ.O.)THEN
                 CALL VAPOR((4-L)/L,PIDFVAP(L),DETECT)
               IF(.NOT.DETECT) VAPFLG=.TRUE.
          PIDFSPH(L)=.0313*POR*VAPWDIS((4-L)/L)**3
              ENDIF
              IF(.NOT.VAPFLG) THEN
                SPHTIME=PIDFSPH(L)/PIDEFRT(L)
IF((VTIME((4-L)/L)*PIDEFRT(L)).GT.PIDFSPH(L).AND.MAX(SPHTIME,
   PIDFVAP(L)).EQ.PIDFVAP(L)) THEN
                 IF(PIDFVAP(L).GT.43200.) THEN
                     PIDFVAP(L)=PIDFVAP(L)-43200.
                     DETECT=.FALSE.
                    ELSE
                     DETECT=.TRUE.
                     DETTIME=PIDFVAP(L)+1440
                     VAPDET=.TRUE.
                   ENDIF
                   PIDFSPH(L)=PIDFSPH(L)-MINMO*PIDEFRT(L)
    ELSE
       DETECT=.FALSE.
       IF(SPHTIME.LT.MINMO)THEN
         DETECT=.TRUE.
         DETTIME=SPHTIME+1440
         VAPDET=.TRUE.
       ELSE
         DETECT=.FALSE.
         PIDFSPH(L)=PIDFSPH(L)-MINMO*PIDEFRT(L)
         PIDFVAP(L)=PIDFVAP(L)-43200
       ENDIF
    ENDIF
                ENDIF
                ENDIF
          IF(DETECT)GO TO 1
          ENDIF
        ENDIF
    ENDIF
    IF(UGPIPE)THEN
       IF(INVCNTL)THEN
       CALL IMMINV(1,L,PIDEFRT(L),DETECT,DETTIME)
       DLAB='II'
       IF(DETECT) GO TO 1
       ENDIF
       IF(MONMETH(5))THEN
         DLAB='VW'
          IF((PIPCONT(L).EQ.K).OR.(.NOT.PIPSEC))THEN
           IF(.NOT.VAPFLG)THEN
           IF(PIDFVAP(L).EQ.O.)THEN
                CALL VAPOR((4-L)/L,PIDFVAP(L),DETECT)
              IF(.NOT.DETECT) VAPFLG=.TRUE.
         PIDFSPH(L)=.0313*POR*VAPWDIS((4-L)/L)**3
             ENDIF
             IF(.NOT.VAPFLG) THEN
               SPHTIME=PIDFSPH(L)/PIDEFRT(L)
```

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IF ((VTIME (-(4-L)/L) *PIDEFRT (L)) .GT.PIDFSPH (L) :AND.MAX (SPHTIME,
   PIDFVAP (L)) .EQ.PIDFVAP (L))  THEN
                IF (PIDFVAP (L) .GT.43200.)  THEN
                    PIDFVAP (L) =PIDFVAP (L) -43200.
                    DETECT=.FALSE.
                   ELSE
                    DETECT=.TRUE.
                    DETTIME=PIDFVAP (L) +1440
                    VAPDET=.TRUE.
                  ENDIF
                  PIDFSPH (L) =PIDFSPH (L) -MINMO*PIDEFRT (L)
    ELSE
       DETECT=.FALSE.
       IF (SPHTIME.LT.MINMO) THEN
         DETECT=.TRUE.
         DETTIME=SPHTIME+1440
         VAPDET=.TRUE.
       ELSE
         DETECT=.FALSE.
         PIDFSPH (L) =PIDFSPH (L) -MINMO*PIDEFRT (L)
         PIDFVAP (L) =PIDFVAP (L) -43200
       ENDIF
    ENDIF
                ENDIF
                ENDIF
             IF (DETECT) GO TO 1
          ENDIF
       ENDIF
    ENDIF
    IF (PIDEFVL (L) .EQ.0) THEN
      MOFRAC=FNU (0.,1.)
        IF (L.EQ.1) THEN
  PIDEFVL (L) =PIDEFRT (L) *DAYMO*FILLFR (L) *FILLTIM (L) *MOFRAC
 IF (((MAX ((PIDEFVL (L) /PIDEFRT (L)) ,PREMDT)) -PREMDT) .NE.0)  THEN
          PREMDT=PIDEFVL (L) /PIDEFRT (L)
          PREMRT=PIDEFRT (L)
        ENDIF
           ELSE
   PIDEFVL (L) =PIDEFRT (L) *DAYMO*MOFRAC*DISCFR (L) *DISCTIM (L)
 IF (((MAX ((PIDEFVL (L) /PIDEFRT (L)) ,PREMDT)) -PREMDT) .NE.0)  THEN
          PREMDT=PIDEFVL (L) /PIDEFRT (L)
          PREMRT=PIDEFRT (L)
        ENDIF
          ENDIF
       ELSE
        IF (L.EQ.1) THEN
          PIDEFVL (L) =PIDEFRT (L) *DAYMO*FILLFR (L) *FILLTIM (L)
 IF (((MAX ((PIDEFVL (L) /PIDEFRT (L)) ,PREMDT)) -PREMDT) .NE.0)  THEN
          PREMDT=PIDEFVL (L) /PIDEFRT (L)
          PREMRT=PIDEFRT (L)
        ENDIF
        ELSE
          PIDEFVL (L) =PIDEFRT (L) *DAYMO*DISCFR (L) *DISCTIM (L)
 IF (((MAX ((PIDEFVL (L) /PIDEFRT (L)) ,PREMDT)) -PREMDT) .NE.0)  THEN
          PREMDT=PIDEFVL (L) /PIDEFRT (L)
          PREMRT=PIDEFRT (L)
        ENDIF
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              ENDIF
                ENDIF
         IF(AGPIPE)THEN
          IF(PIPCONT(L).EQ.K)THEN
             TSURF=PAGFRAC*PIDEFVL(L)+TSURF
             TSUB=(1-PAGFRAC)*PIDEFVL(L)+TSUB
          PIVOL(L)=PIVOL(L)+PIDEFVL(L)*(1-PAGFRAC)
           ELSE
            TSURF=PIDEFVL(L)+TSURF
         ENDIF
        ELSE
           TSUB=PIDEFVL(L)+TSUB
          PIVOL(L)=PIVOL(L)+PIDEFVL(L)
        ENDIF
        DO 807 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.ITYPFLG)  THEN
            IF(FALNUM7(II).EQ.((YR-1)*12+K))THEN
             FALNUM2(II)=PIDEFVL(L)
             FALNUM5(II)=MOFRAC*720
            ELSE
             FALNUM2(II)=FALNUM2(II)+PIDEFVL(L)
             FALNUM5(II)=FALNUM5(II)+720
            ENDIF
           FALNUM3(II)=((YR-1)*12)+K
            GO TO 808
          ENDIF
          807 CONTINUE
          808 CONTINUE
         GO TO 2
   1     DEFREL=PIDEFRT(L)*DETTIME
IF((L.EQ.1).AND.(.NOT.((AGTANK.AND.VERT.AND.(TNKCAP(1)
+   .GT.1000))).OR.(IGTANK.AND.(FRACTUG.LT..5))))THEN
   IF(DEFREL.GT.(FILLVOL(1)*FILLFR(1)*DAYMO))DEFREL=
+       FILLVOL(1)*FILLFR(1)*DAYMO
ELSEIF((L.NE.1).AND.(.NOT.((IGTANK.AND.(FRACTUG.LT..5))
+   .OR.AGTANK)))THEN
   IF(DEFREL.GT.(FILLVOL(1)*FILLFR(1)*DAYMO))DEFREL=
+       FILLVOL(1)*FILLFR(1)*DAYMO
ELSE
IF(DEFREL.GT.(TNKCAP(L-1+1/L-L/5)*OPLEV))THEN
         DEFREL=TNKCAP(L-1+1/L-L/5)*OPLEV
       ENDIF
ENDIF
        DO 809 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.ITYPFLG)THEN
            FALNUM2(II)=FALNUM2(II)+DEFREL
            FALNUM5(II)=FALNUM5(II)+DETTIME/60.
            GO TO 810
          ENDIF
          809 CONTINUE
          810 CONTINUE
          FALNUM3(II)=((YR-1)*12)+K
      IF(AGPIPE)THEN
         IF(PIPCONT(L).EQ.K)  THEN
                TEMP=TSURF+SURF+PAGFRAC*DEFREL
           CALL CLENUP(TEMP)
     TSURF=0
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       SURF=0
     TPRSURF=0
     PRSURF=0
             DEFREL=(1-PAGFRAC)*DEFREL
          AGRUPT=DEFREL+AGRUPT
           ELSE
          DEFREL=DEFREL+TSURF+SURF
            CALL CLENUP(DEFREL)
       TSURF=0
       SURF=0
     TPRSURF=0
     PRSURF=0
                DEFREL=0.
           ENDIF
            ELSE
             UGRUPT=DEFREL+UGRUPT
          ENDIF
           PIVOL(L)=PIVOL(L)+DEFREL
          MONREL=DEFREL+MONREL
          DETECT=.FALSE.
          IF (((MAX(DETTIME,PREMDT))-PREMDT).NE.0) THEN
             PREMDT=DETTIME
             PREMRT=PIDEFRT(L)
          ENDIF
        CALL FIX(DLAB,K,YR,L,6)
        CALL FIX(DLAB,K,YR,L,4)
        CALL FIX(DLAB,K,YR,L,9)
        CALL VAPZERO(1,L)
       IF(GKDEFVL(L).GT.0) CALL FIX(DLAB,K,YR,L,8)
       IF(WLDEFVL(L).GT.0) CALL FIX(DLAB,K,YR,L,7)
          IF(RPPIVOL(L).GT.0) CALL FIX(DLAB,K,YR,L,5)
          IF(RPWLVOL(L).GT.0) CALL FIX(DLAB,K,YR,L,10)
    ENDIF
      2 CONTINUE
       DEFREL=0
   51 CONTINUE
   DO 52 L=1,NPI
*   RUPTURED PIPE
      IF(RUPPIP(L).EQ.K)THEN
      ITYPFLG=2010+L
***NOT A CONTINUOUS LEAK
         IF(RPPIVOL(L).EQ.0)THEN
         FALNUM=FALNUM+1
         FALNUM1(FALNUM)=ITYPFLG
         FALNUM7(FALNUM)=(YR-1)*12+K
             ONGO=.FALSE.
            CALL LEAKRT(ONGO,1,L,0,LKRATE,DM,RPPIWID(L),RPPILEN(L))
            RPPIRT(L)=LKRATE
         ENDIF
 DETECT=.FALSE.
 IF(MONMETH(7).AND.PIPSEC)THEN
    DLAB='IS'
* INTERSTITIAL MONITORING
    PIINTER(L,2)=FNB(PIINTER(L,1))
    IF(PIINTER(L,2).EQ.0)THEN
       DETTIME=FNU(60.,720.)
       DETECT=.TRUE.
    GO TO 101
  ENDIF
ENDIF
     DETECT=.FALSE.
     IF(AGPIPE)THEN
        TMIN=.25
        IF(BATCH)T2=CONTVOL(L)/FLOWRT(L)
    IF(CONT)THEN
      T2=(24-OPHRSDY)*60.
      IF(T2.LT.(4.*60.))T2=4.*60.
     ENDIF
        T1=.25*T2
       CALL RATEDET(RPPIRT(L),TMIN,T1,T2,DETECT,DETTIME)
       DLAB='RD'
       IF(DETECT) GO TO 101
       IF(INVCNTL)THEN
       CALL IMMINV(1,L,RPPIRT(L),DETECT,DETTIME)
       DLAB='II'
       IF(DETECT) GO TO 101
       ENDIF
       IF(MONMETH(5))THEN
         DLAB='VW'
         IF((PIPCONT(L).EQ.K).OR.(.NOT.PIPSEC))THEN
          IF(.NOT.VAPFLG)THEN
          IF(PIRPVAP(L).EQ.0.)THEN
             CALL VAPOR((4-L)/L,PIRPVAP(L),DETECT)
            IF(.NOT.DETECT) VAPFLG=.TRUE.
         PIRPSPH(L)=.0313*POR*VAPWDIS((4-L)/L)**3
           ENDIF
           IF(.NOT.VAPFLG) THEN
             SPHTIME=PIRPSPH(L)/RPPIRT(L)
   IF((VTIME((4-L)/L)*RPPIRT(L)).GT.PIRPSPH(L).AND.MAX(SPHTIME,
     PIRPVAP(L)).EQ.PIRPVAP(L)) THEN
             IF(PIRPVAP(L).GT.43200.) THEN
                PIRPVAP(L)=PIRPVAP(L)-43200.
                DETECT=.FALSE.
               ELSE
                DETECT=.TRUE.
                DETTIME=PIRPVAP(L)+1440
                VAPDET=.TRUE.
              ENDIF
              PIRPSPH(L)=PIRPSPH(L)-MINMO*RPPIRT(L)
     ELSE
       DETECT=.FALSE.
       IF(SPHTIME.LT.MINMO)THEN
         DETECT=.TRUE.
         DETTIME=SPHTIME+1440
         VAPDET=.TRUE.
       ELSE
         DETECT=.FALSE.
         PIRPSPH(L)=PIRPSPH(L)-MINMO*RPPIRT(L)
         PIRPVAP(L)=PIRPVAP(L)-43200
       ENDIF
     ENDIF
             ENDIF
             ENDIF
         IF(DETECT)GO TO 101
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          ENDIF
        ENDIF
    ENDIF
    IF(UGPIPE)THEN
       IF(INVCNTL)THEN
       CALL IMMINV(1,L,RPPIRT(L),DETECT,DETTIME)
       DLAB='II'
       IF(DETECT) GO TO 101
       ENDIF
       IF(MONMETH(5))THEN
         DLAB='VW'
          IF((PIPCONT(L).EQ.K).OR.(.NOT.PIPSEC))THEN
           IF(.NOT.VAPFLG)THEN
           IF(PIRPVAP(L).EQ.O.)THEN
                CALL VAPOR((4-L)/L,PIRPVAP(L),DETECT)
              IF(.NOT.DETECT) VAPFLG=.TRUE.
         PIRPSPH(L)=.0313*POR*VAPWDIS((4-L)/L)**3
             ENDIF
             IF(.NOT.VAPFLG) THEN
               SPHTIME=PIRPSPH(L)/RPPIRT(L)
IF((VTIME((4-L)/L)*RPPIRT(L)).GT.PIRPSPH(L).AND.MAX(SPHTIME,
   PIRPVAP(L)).EQ.PIRPVAP(L)) THEN
                 IF(PIRPVAP(L).GT.43200.) THEN
                     PIRPVAP(L)=PIRPVAP(L)-43200.
                     DETECT=.FALSE.
                    ELSE
                     DETECT=.TRUE.
                     DETTIME=PIRPVAP(L)+1440
                     VAPDET=.TRUE.
                   ENDIF
                   PIRPSPH(L)=PIRPSPH(L)-MINMO*RPPIRT(L)
    ELSE
       DETECT=.FALSE.
       IF(SPHTIME.LT.MINMO)THEN
         DETECT=.TRUE.
         DETTIME=SPHTIME+1440
         VAPDET=.TRUE.
       ELSE
         DETECT=.FALSE.
         PIRPSPH(L)=PIRPSPH(L)-MINMO*RPPIRT(L)
         PIRPVAP(L)=PIRPVAP(L)-43200
       ENDIF
    ENDIF
                ENDIF
                ENDIF
             IF(DETECT)GO TO 101
          ENDIF
       ENDIF
    ENDIF
    IF(RPPIVOL(L).EQ.O)THEN
      MOFRAC=FNU(O.,1.)
        IF(L.EQ.1)THEN
       RPPIVOL(L)=RPPIRT(L)*DAYMO*FILLFR(L)*FILLTIM(L)*MOFRAC
 IF(((MAX((RPPIVOL(L)/RPPIRT(L)),PREMDT))-PREMDT).NE.O) THEN
          PREMDT=RPPIVOL(L)/RPPIRT(L)
          PREMRT=RPPIRT(L)
        ENDIF
```

```
            ELSE
      RPPIVOL(L)=RPPIRT(L)*DAYMO*MOFRAC*DISCFR(L)*DISCTIM(L)
    IF(((MAX((RPPIVOL(L)/RPPIRT(L)),PREMDT))-PREMDT).NE.0)  THEN
            PREMDT=RPPIVOL(L)/RPPIRT(L)
            PREMRT=RPPIRT(L)
          ENDIF
            ENDIF
         ELSE
          IF(L.EQ.1)THEN
            RPPIVOL(L)=RPPIRT(L)*DAYMO*FILLFR(L)*FILLTIM(L)
    IF(((MAX((RPPIVOL(L)/RPPIRT(L)),PREMDT))-PREMDT).NE.0)  THEN
           PREMDT=RPPIVOL(L)/RPPIRT(L)
           PREMRT=RPPIRT(L)
          ENDIF
          ELSE
           RPPIVOL(L)=RPPIRT(L)*DAYMO*DISCFR(L)*DISCTIM(L)
    IF(((MAX((RPPIVOL(L)/RPPIRT(L)),PREMDT))-PREMDT).NE.0)  THEN
           PREMDT=RPPIVOL(L)/RPPIRT(L)
           PREMRT=RPPIRT(L)
          ENDIF
          ENDIF
         ENDIF
      IF(AGPIPE)THEN
       IF(PIPCONT(L).EQ.K)THEN
         TSURF=PAGFRAC*RPPIVOL(L)+TSURF
         TSUB=(1-PAGFRAC)*RPPIVOL(L)+TSUB
       PIVOL(L)=PIVOL(L)+RPPIVOL(L)*(1-PAGFRAC)
        ELSE
         TSURF=RPPIVOL(L)+TSURF
       ENDIF
      ELSE
        TSUB=RPPIVOL(L)+TSUB
       PIVOL(L)=PIVOL(L)+RPPIVOL(L)
      ENDIF
      DO 907 II=FALNUM,1,-1
        IF(FALNUM1(II).EQ.ITYPFLG)  THEN
         IF(FALNUM7(II).EQ.((YR-1)*12+K))THEN
          FALNUM2(II)=RPPIVOL(L)
          FALNUM5(II)=MOFRAC*720
         ELSE
          FALNUM2(II)=FALNUM2(II)+RPPIVOL(L)
          FALNUM5(II)=FALNUM5(II)+720
         ENDIF
        FALNUM3(II)=((YR-1)*12)+K
         GO TO 908
       ENDIF
       907 CONTINUE
       908 CONTINUE
      GO TO 102
  101      RUPREL=RPPIRT(L)*DETTIME
 IF((L.EQ.1).AND.(.NOT.((AGTANK.AND.VERT.AND.(TNKCAP(1)
   .GT.1000))).OR.(IGTANK.AND.(FRACTUG.LT..5))))THEN
   IF(RUPREL.GT.(FILLVOL(1)*FILLFR(1)*DAYMO))RUPREL=
       FILLVOL(1)*FILLFR(1)*DAYMO
ELSEIF((L.NE.1).AND.(.NOT.((IGTANK.AND.(FRACTUG.LT..5))
   .OR.AGTANK)))THEN
   IF(RUPREL.GT.(FILLVOL(1)*FILLFR(1)*DAYMO))RUPREL=
+        FILLVOL(1)*FILLFR(1)*DAYMO
 ELSE
 IF(RUPREL.GT.(TNKCAP(L-1+1/L-L/5)*OPLEV))THEN
             RUPREL=TNKCAP(L-1+1/L-L/5)*OPLEV
         ENDIF
 ENDIF
         DO 909 II=FALNUM,1,-1
           IF(FALNUM1(II).EQ.ITYPFLG)THEN
             FALNUM2(II)=FALNUM2(II)+RUPREL
             FALNUM5(II)=FALNUM5(II)+DETTIME/60.
             GO TO 910
           ENDIF
           909 CONTINUE
           910 CONTINUE
           FALNUM3(II)=((YR-1)*12)+K
         IF(AGPIPE)THEN
          IF(PIPCONT(L).EQ.K)  THEN
                    TEMP=TSURF+SURF+PAGFRAC*RUPREL
             CALL CLENUP(TEMP)
      TSURF=0
      SURF=0
    TPRSURF=0
    PRSURF=0
             RUPREL=(1-PAGFRAC)*RUPREL
         AGRUPT=RUPREL+AGRUPT
          ELSE
      RUPREL=RUPREL+TSURF+SURF
           CALL CLENUP(RUPREL)
      TSURF=0
      SURF=0
    TPRSURF=0
    PRSURF=0
                RUPREL=0.
          ENDIF
           ELSE
            UGRUPT=RUPREL+UGRUPT
         ENDIF
       PIVOL(L)=PIVOL(L)+RUPREL
         MONREL=RUPREL+MONREL
         DETECT=.FALSE.
         IF  (((MAX(DETTIME,PREMDT))-PREMDT).NE.0)  THEN
            PREMDT=DETTIME
            PREMRT=RPPIRT(L)
         ENDIF
       CALL FIX(DLAB,K,YR,L,5)
       CALL FIX(DLAB,K,YR,L,4)
       CALL FIX(DLAB,K,YR,L,9)
     CALL VAPZERO(1,L)
      IF(PIDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,6)
      IF(GKDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,8)
      IF(WLDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,7)
         IF(RPWLVOL(L).GT.0)  CALL FIX(DLAB,K,YR,L,10)
      102 CONTINUE
      ENDIF
       RUPREL=0
   52 CONTINUE
    DO 5222 L=1,NTK
```

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31615* TANK INSTALLATION DEFICEINCY.
31620   IF(TNKDEF(L).EQ.K)THEN
31625      ITYPFLG=1030+L
31630      IF(TKDEFVL(L).EQ.0)THEN
31635         FALNUM=FALNUM+1
31640         FALNUM1(FALNUM)=ITYPFLG
31645         FALNUM7(FALNUM)=(YR-1)*12+K
31650*****    NOT A CONTINUOUS LEAK
31655             ONGO=.FALSE.
31660    CALL LEAKRT(ONGO,3,1,0,LKRATE,DM,TKDFWID(L),TKDFLEN(L))
31665         TKDEFRT(L)=LKRATE
31670      ENDIF
31675      DETECT=.FALSE.
31680      IF(MONMETH(2).AND.VAULT)THEN
31685      DLAB='IS'
31690******    INTERSTITIAL MONITORING
31695         INTERST(L,2)=FNB(INTERST(L,1))
31700         IF(INTERST(L,2).EQ.0)THEN
31705            DETTIME=FNU(60.,720.)
31710            DETECT=.TRUE.
31715            GO TO 5
31720         ENDIF
31725      ENDIF
31730      IF(AGTANK.AND.CRADLE)THEN
31735             TMIN=30.
31740             T2=MINMO
31745          IF(WEEKINS)T2=10080.
31750       IF(CONT)THEN
31755          T2=(24-OPHRSDY)*60.
31760          IF(T2.LT.(4.*60.))T2=4.*60.
31765        ENDIF
31770             T1=T2
31775        CALL RATEDET(TKDEFRT(L),TMIN,T1,T2,DETECT,DETTIME)
31780    IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
31785           DLAB='RD'
31790 IF((CONT.AND.STORAGE).AND.(DETTIME.GT.(OPLEV*TNKCAP(L)/TKDEFRT(L))
31795+  ))DETTIME=OPLEV*TNKCAP(L)/TKDEFRT(L)
31800 IF(DETTIME.GT.(TNKCAP(L)/TKDEFRT(L)))DETTIME=TNKCAP(L)/
31805+  TKDEFRT(L)
31810         IF(DETECT) GO TO 5
31815         IF(INVCNTL)THEN
31820         CALL IMMINV(3,1,TKDEFRT(L),DETECT,DETTIME)
31825            DLAB='II'
31830         IF(DETECT) GO TO 5
31835         ENDIF
31840         IF(MONMETH(5))THEN
31845              DLAB='VW'
31850 IF((AGCONT(L).EQ.K).OR.(AGTANK.AND.(.NOT.CRADLE)).OR.(NOSECON))
31855+THEN
31860                IF(.NOT.VAPFLG)THEN
31865                IF(TKDFVAP.EQ.0.)THEN
31870                     CALL VAPOR(3,TKDFVAP,DETECT)
31875                   IF(.NOT.DETECT) VAPFLG=.TRUE.
31880              TKDFSPH=.0313*POR*VAPWDIS(3)**3
31885                  ENDIF
31890                  IF(.NOT.VAPFLG) THEN
31895                    SPHTIME=TKDFSPH/TKDEFRT(L)
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      IF((VTIME(3)*TKDEFRT(L)).GT.TKDFSPH.AND.MAX(SPHTIME,
         TKDFVAP).EQ.TKDFVAP) THEN
                       IF(TKDFVAP.GT.43200.) THEN
                           TKDFVAP=TKDFVAP-43200.
                           DETECT=.FALSE.
                          ELSE
                           DETECT=.TRUE.
                           DETTIME=TKDFVAP+1440
                           VAPDET=.TRUE.
                         ENDIF
                         TKDFSPH=TKDFSPH-MINMO*TKDEFRT(L)
          ELSE
             DETECT=.FALSE.
             IF(SPHTIME.LT.MINMO)THEN
               DETECT=.TRUE.
               DETTIME=SPHTIME+1440
               VAPDET=.TRUE.
             ELSE
               DETECT=.FALSE.
               TKDFSPH=TKDFSPH-MINMO*TKDEFRT(L)
               TKDFVAP=TKDFVAP-43200
             ENDIF
         ENDIF
                      ENDIF
                      ENDIF
                IF(DETECT) GO TO 5
            ENDIF
         ENDIF
      ENDIF
      IF(UGTANK.OR.IGTANK)THEN
         IF(INVCNTL)THEN
         CALL IMMINV(3,1,TKDEFRT(L),DETECT,DETTIME)
            DLAB='II'
         IF(DETECT) GO TO 5
         ENDIF
         IF(MONMETH(5))THEN
              DLAB='VW'
            IF((UGCONT(L).EQ.K).OR.NOSECON)THEN
                IF(.NOT.VAPFLG)THEN
                IF(TKDFVAP.EQ.0.)THEN
                     CALL VAPOR(3,TKDFVAP,DETECT)
                   IF(.NOT.DETECT) VAPFLG=.TRUE.
              TKDFSPH=.0313*POR*VAPWDIS(3)**3
                  ENDIF
                  IF(.NOT.VAPFLG) THEN
                    SPHTIME=TKDFSPH/TKDEFRT(L)
      IF((VTIME(3)*TKDEFRT(L)).GT.TKDFSPH.AND.MAX(SPHTIME,
         TKDFVAP).EQ.TKDFVAP) THEN
                       IF(TKDFVAP.GT.43200.) THEN
                           TKDFVAP=TKDFVAP-43200.
                           DETECT=.FALSE.
                          ELSE
                           DETECT=.TRUE.
                           DETTIME=TKDFVAP+1440
                           VAPDET=.TRUE.
                         ENDIF
                         TKDFSPH=TKDFSPH-MINMO*TKDEFRT(L)
```

```
32185          ELSE
32190             DETECT=.FALSE.
32195             IF(SPHTIME.LT.MINMO)THEN
32200               DETECT=.TRUE.
32205               DETTIME=SPHTIME+1440
32210               VAPDET=.TRUE.
32215             ELSE
32220               DETECT=.FALSE.
32225               TKDFSPH=TKDFSPH-MINMO*TKDEFRT(L)
32230               TKDFVAP=TKDFVAP-43200
32235             ENDIF
32240          ENDIF
32245                      ENDIF
32250                      ENDIF
32255                IF(DETECT)GO TO 5
32260             ENDIF
32265          ENDIF
32270       ENDIF
32275      IF(TKDEFVL(L).EQ.0)THEN
32280           MOFRAC=FNU(0.,1.)
32285*****     LEAKS FOR A FULL MONTH IF NOT DETECTED IN PRIOR MONTH
32290          TKDEFVL(L)=TKDEFRT(L)*MINMO*MOFRAC*TANKTIM(L)
32295      IF(((MAX((TKDEFVL(L)/TKDEFRT(L)),TREMDT))-TREMDT).NE.0) THEN
32300                TREMDT=TKDEFVL(L)/TKDEFRT(L)
32305                TREMRT=TKDEFRT(L)
32310              ENDIF
32315           IF(TKDEFVL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))THEN
32320              TKDEFVL(L)=FILLVOL(1)*FILLFR(1)*30.
32325           ENDIF
32330         ELSE
32335          TKDEFVL(L)=TKDEFRT(L)*MINMO*TANKTIM(L)
32340      IF(((MAX((TKDEFVL(L)/TKDEFRT(L)),TREMDT))-TREMDT).NE.0) THEN
32345                TREMDT=TKDEFVL(L)/TKDEFRT(L)
32350                TREMRT=TKDEFRT(L)
32355              ENDIF
32360           IF(TKDEFVL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))THEN
32365             TKDEFVL(L)=FILLVOL(1)*FILLFR(1)*30.
32370          ENDIF
32375      ENDIF
32380      IF(AGTANK.AND.CRADLE)THEN
32385         IF((AGCONT(L).EQ.K).OR.(AGTANK.AND.(.NOT.CRADLE)))THEN
32390            TSURF=AGCONFR*TKDEFVL(L)+TSURF
32395            TSUB=(1-AGCONFR)*TKDEFVL(L)+TSUB
32400       TKVOL(L)=TKVOL(L)+TKDEFVL(L)*(1-AGCONFR)
32405           ELSE
32410            TSURF=TKDEFVL(L)+TSURF
32415         ENDIF
32420        ELSE
32425*****     UGTANK.OR.IGTANK
32430      IF((UGCONT(L).EQ.K).OR.NOSECON.OR.(.NOT.VAULT))THEN
32435            TSURF=(UGCONFR)*TKDEFVL(L)+TSURF
32440            TSUB=(1-UGCONFR)*TKDEFVL(L)+TSUB
32445       TKVOL(L)=TKVOL(L)+TKDEFVL(L)*(1-UGCONFR)
32450           ELSE
32455            TSURF=TKDEFVL(L)+TSURF
32460         ENDIF
32465      ENDIF
```

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       DO 1002 II=FALNUM,1,-1
         IF (FALNUM1 (II) .EQ.ITYPFLG)  THEN
            IF (FALNUM7 (II) .EQ. ((YR-1) *12+K)) THEN
             FALNUM2 (II) =TKDEFVL (L)
             FALNUM5 (II) =MOFRAC*720
            ELSE
             FALNUM2 (II) =FALNUM2 (II) +TKDEFVL (L)
             FALNUM5 (II) =FALNUM5 (II) +720
            ENDIF
            GO TO 1003
         ENDIF
         1002 CONTINUE
         1003 CONTINUE
          FALNUM3 (II) = ((YR-1) *12) +K
     GO TO 6
5    DEFREL=TKDEFRT (L) *DETTIME
       IF (DEFREL.GT. (TNKCAP (L) *OPLEV)) THEN
             DEFREL=TNKCAP (L) *OPLEV
        ENDIF
        DO 1004 II=FALNUM,1,-1
          IF (FALNUM1 (II) .EQ.ITYPFLG) THEN
             FALNUM2 (II) =FALNUM2 (II) +DEFREL
             FALNUM5 (II) =FALNUM5 (II) +DETTIME/60.
            GO TO 1034
          ENDIF
          1004 CONTINUE
          1034 CONTINUE
          FALNUM3 (II) = ((YR-1) *12) +K
     IF (AGTANK.AND.CRADLE) THEN
         IF ((AGCONT (L) .EQ.K) .OR. (AGTANK.AND. (.NOT.CRADLE)))  THEN
                  TEMP=TSURF+SURF+AGCONFR*DEFREL
           CALL CLENUP (TEMP)
    TSURF=0
    SURF=0
  TPRSURF=0
  PRSURF=0
           DEFREL= (1-AGCONFR) *DEFREL
        AGRUPT=DEFREL+AGRUPT
         ELSE
        DEFREL=DEFREL+TSURF+SURF
          CALL CLENUP (DEFREL)
    TSURF=0
    SURF=0
  TPRSURF=0
  PRSURF=0
                  DEFREL=0.
         ENDIF
      ELSE
   IF ((UGCONT (L) .EQ.K) .OR.NOSECON.OR. (.NOT.VAULT))  THEN
                TEMP=TSURF+SURF+UGCONFR*DEFREL
           CALL CLENUP (TEMP)
    TSURF=0
    SURF=0
  TPRSURF=0
  PRSURF=0
           DEFREL= (1-UGCONFR) *DEFREL
       UGRUPT=DEFREL+UGRUPT
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         ELSE
        DEFREL=DEFREL+TSURF+SURF
          CALL CLENUP(DEFREL)
     TSURF=0
     SURF=0
   TPRSURF=0
   PRSURF=0
                 DEFREL=0.
         ENDIF
     ENDIF
     MONREL=DEFREL+MONREL
         TKVOL(L)=TKVOL(L)+DEFREL
     DETECT=.FALSE.
        IF (((MAX(DETTIME,TREMDT))-TREMDT).NE.0) THEN
           TREMDT=DETTIME
           TREMRT=TKDEFRT(L)
        ENDIF
       IF(YRO.NE.O.AND.IYRNUM.LT.YRO)TANKREP=.TRUE.
      CALL FIX(DLAB,K,YR,L,3)
   CALL VAPZERO(3,1)
  CALL FIX(DLAB,K,YR,L,1)
            DO 816 LL=1,NPI
      CALL FIX(DLAB,K,YR,LL,9)
     IF(WLDEFVL(LL).GT.0) CALL FIX(DLAB,K,YR,LL,7)
     IF(GKDEFVL(LL).GT.0) CALL FIX(DLAB,K,YR,LL,8)
        IF(RPWLVOL(LL).GT.0) CALL FIX(DLAB,K,YR,LL,10)
          816 CONTINUE
        IF(RPTKVOL(L).GT.0) CALL FIX(DLAB,K,YR,L,2)
  ENDIF
6 CONTINUE
   DEFREL=0
   5222 CONTINUE
   DO 5223 L=1,NTK
*  RUPTURED TANK
  IF(RUPTNK(L).EQ.K)THEN
     ITYPFLG=2030+L
     IF(RPTKVOL(L).EQ.0)THEN
        FALNUM=FALNUM+1
        FALNUM1(FALNUM)=ITYPFLG
        FALNUM7(FALNUM)=(YR-1)*12+K
*****   NOT A CONTINUOUS LEAK
            ONGO=.FALSE.
         RPSEAM(1)=.75
         RPSEAM(2)=FNB(RPSEAM(1))
          IF(RPSEAM(2).EQ.1.)THEN
*         SEAM RUPTURE
            LKRUP=2
           ELSE
            LKRUP=0
        ENDIF
 CALL LEAKRT(ONGO,3,1,LKRUP,LKRATE,DM,RPTKWID(L),RPTKLEN(L))
        RPTKRT(L)=LKRATE
     ELSE
*    APPLY GROWTH RATE
     ENDIF
     DETECT=.FALSE.
     IF(MONMETH(2).AND.VAULT)THEN
```

```
33040      DLAB='IS'
33045******    INTERSTITIAL MONITORING
33050         INTERST(L,2)=FNB(INTERST(L,1))
33055         IF(INTERST(L,2).EQ.0)THEN
33060           DETTIME=FNU(60.,720.)
33065            DETECT=.TRUE.
33070        GO TO 105
33075         ENDIF
33080      ENDIF
33085      IF(AGTANK.AND.CRADLE)THEN
33090             TMIN=30.
33095             T2=MINMO
33100          IF(WEEKINS)T2=10080.
33105       IF(CONT)THEN
33110          T2=(24-OPHRSDY)*60.
33115          IF(T2.LT.(4.*60.))T2=4.*60.
33120        ENDIF
33125             T1=T2
33130        CALL RATEDET(RPTKRT(L),TMIN,T1,T2,DETECT,DETTIME)
33135    IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
33140           DLAB='RD'
33145 IF((CONT.AND.STORAGE).AND.(DETTIME.GT.(OPLEV*TNKCAP(L)/RPTKRT(L))
33150+  ))DETTIME=OPLEV*TNKCAP(L)/RPTKRT(L)
33155     IF(DETTIME.GT.(TNKCAP(L)/RPTKRT(L)))DETTIME=TNKCAP(L)/
33160+  RPTKRT(L)
33165         IF(DETECT) GO TO 105
33170         IF(INVCNTL)THEN
33175         CALL IMMINV(3,1,RPTKRT(L),DETECT,DETTIME)
33180            DLAB='II'
33185         IF(DETECT) GO TO 105
33190         ENDIF
33195         IF(MONMETH(5))THEN
33200              DLAB='VW'
33205 IF((AGCONT(L).EQ.K).OR.(AGTANK.AND.(.NOT.CRADLE)).OR.(NOSECON))
33210+THEN
33215                IF(.NOT.VAPFLG)THEN
33220                IF(TKRPVAP.EQ.0.)THEN
33225                     CALL VAPOR(3,TKRPVAP,DETECT)
33230                   IF(.NOT.DETECT) VAPFLG=.TRUE.
33235              TKRPSPH=.0313*POR*VAPWDIS(3)**3
33240                  ENDIF
33245                  IF(.NOT.VAPFLG) THEN
33250                    SPHTIME=TKRPSPH/RPTKRT(L)
33255     IF((VTIME(3)*RPTKRT(L)).GT.TKRPSPH.AND.MAX(SPHTIME,
33260+      TKRPVAP).EQ.TKRPVAP) THEN
33265                     IF(TKRPVAP.GT.43200.) THEN
33270                         TKRPVAP=TKRPVAP-43200.
33275                         DETECT=.FALSE.
33280                        ELSE
33285                         DETECT=.TRUE.
33290                         DETTIME=TKRPVAP+1440
33295                         VAPDET=.TRUE.
33300                       ENDIF
33305                       TKRPSPH=TKRPSPH-MINMO*RPTKRT(L)
33310         ELSE
33315            DETECT=.FALSE.
33320            IF(SPHTIME.LT.MINMO)THEN
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```
         DETECT=.TRUE.
         DETTIME=SPHTIME+1440
         VAPDET=.TRUE.
       ELSE
         DETECT=.FALSE.
         TKRPSPH=TKRPSPH-MINMO*RPTKRT(L)
         TKRPVAP=TKRPVAP-43200
       ENDIF
    ENDIF
                ENDIF
                ENDIF
          IF(DETECT) GO TO 105
       ENDIF
    ENDIF
 ENDIF
 IF(UGTANK.OR.IGTANK)THEN
    IF(INVCNTL)THEN
    CALL IMMINV(3,1,RPTKRT(L),DETECT,DETTIME)
       DLAB='II'
    IF(DETECT) GO TO 105
    ENDIF
    IF(MONMETH(5))THEN
         DLAB='VW'
       IF((UGCONT(L).EQ.K).OR.NOSECON)THEN
           IF(.NOT.VAPFLG)THEN
           IF(TKRPVAP.EQ.O.)THEN
                CALL VAPOR(3,TKRPVAP,DETECT)
              IF(.NOT.DETECT) VAPFLG=.TRUE.
         TKRPSPH=.0313*POR*VAPWDIS(3)**3
             ENDIF
             IF(.NOT.VAPFLG) THEN
               SPHTIME=TKRPSPH/RPTKRT(L)
IF((VTIME(3)*RPTKRT(L)).GT.TKRPSPH.AND.MAX(SPHTIME,
 TKRPVAP).EQ.TKRPVAP) THEN
                IF(TKRPVAP.GT.43200.) THEN
                    TKRPVAP=TKRPVAP-43200.
                    DETECT=.FALSE.
                   ELSE
                    DETECT=.TRUE.
                    DETTIME=TKRPVAP+1440
                    VAPDET=.TRUE.
                  ENDIF
                  TKRPSPH=TKRPSPH-MINMO*RPTKRT(L)
    ELSE
       DETECT=.FALSE.
       IF(SPHTIME.LT.MINMO)THEN
         DETECT=.TRUE.
         DETTIME=SPHTIME+1440
         VAPDET=.TRUE.
       ELSE
         DETECT=.FALSE.
         TKRPSPH=TKRPSPH-MINMO*RPTKRT(L)
         TKRPVAP=TKRPVAP-43200
       ENDIF
    ENDIF
                ENDIF
                ENDIF
                IF(DETECT)GO TO 105
             ENDIF
          ENDIF
       ENDIF
       IF(RPTKVOL(L).EQ.0)THEN
            MOFRAC=FNU(0.,1.)
*****     LEAKS FOR A FULL MONTH IF NOT DETECTED IN PRIOR MONTH
          RPTKVOL(L)=RPTKRT(L)*MINMO*MOFRAC*TANKTIM(L)
       IF(((MAX((RPTKVOL(L)/RPTKRT(L)),TREMDT))-TREMDT).NE.0)  THEN
                TREMDT=RPTKVOL(L)/RPTKRT(L)
                TREMRT=RPTKRT(L)
              ENDIF
           IF(RPTKVOL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))THEN
              RPTKVOL(L)=FILLVOL(1)*FILLFR(1)*30.
           ENDIF
         ELSE
          RPTKVOL(L)=RPTKRT(L)*MINMO*TANKTIM(L)
       IF(((MAX((RPTKVOL(L)/RPTKRT(L)),TREMDT))-TREMDT).NE.0)  THEN
                TREMDT=RPTKVOL(L)/RPTKRT(L)
                TREMRT=RPTKRT(L)
              ENDIF
           IF(RPTKVOL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))THEN
              RPTKVOL(L)=FILLVOL(1)*FILLFR(1)*30.
           ENDIF
      ENDIF
      IF(AGTANK.AND.CRADLE)THEN
           IF((AGCONT(L).EQ.K).OR.(AGTANK.AND.(.NOT.CRADLE)))  THEN
            TSURF=AGCONFR*RPTKVOL(L)+TSURF
            TSUB=(1-AGCONFR)*RPTKVOL(L)+TSUB
       TKVOL(L)=TKVOL(L)+RPTKVOL(L)*(1-AGCONFR)
           ELSE
            TSURF=RPTKVOL(L)+TSURF
         ENDIF
        ELSE
*****     UGTANK.OR.IGTANK
         IF((UGCONT(L).EQ.K).OR.NOSECON.OR.(.NOT.VAULT))THEN
            TSURF=(UGCONFR)*RPTKVOL(L)+TSURF
            TSUB=(1-UGCONFR)*RPTKVOL(L)+TSUB
       TKVOL(L)=TKVOL(L)+RPTKVOL(L)*(1-UGCONFR)
           ELSE
            TSURF=RPTKVOL(L)+TSURF
         ENDIF
      ENDIF
        DO 1005 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.ITYPFLG)  THEN
            IF(FALNUM7(II).EQ.((YR-1)*12+K))THEN
             FALNUM2(II)=RPTKVOL(L)
             FALNUM5(II)=MOFRAC*720
            ELSE
             FALNUM2(II)=FALNUM2(II)+RPTKVOL(L)
             FALNUM5(II)=FALNUM5(II)+720
            ENDIF
            GO TO 1006
          ENDIF
          1005 CONTINUE
          1006 CONTINUE
           FALNUM3(II)=((YR-1)*12)+K
```

```
    GO TO 106
105   RUPREL=RPTKRT(L)*DETTIME
        IF(RUPREL.GT.(TNKCAP(L)*OPLEV))THEN
             RUPREL=TNKCAP(L)*OPLEV
         ENDIF
         DO 1007 II=FALNUM,1,-1
           IF(FALNUM1(II).EQ.ITYPFLG)THEN
             FALNUM2(II)=FALNUM2(II)+RUPREL
             FALNUM5(II)=FALNUM5(II)+DETTIME/60.
             GO TO 1008
           ENDIF
           1007 CONTINUE
           1008 CONTINUE
           FALNUM3(II)=((YR-1)*12)+K
     IF(AGTANK.AND.CRADLE)THEN
         IF((AGCONT(L).EQ.K).OR.(AGTANK.AND.(.NOT.CRADLE)))  THEN
                 TEMP=TSURF+SURF+AGCONFR*RUPREL
            CALL CLENUP(TEMP)
    TSURF=0
    SURF=0
   TPRSURF=0
   PRSURF=0
            RUPREL=(1-AGCONFR)*RUPREL
         AGRUPT=RUPREL+AGRUPT
          ELSE
    RUPREL=RUPREL+TSURF+SURF
           CALL CLENUP(RUPREL)
    TSURF=0
    SURF=0
   TPRSURF=0
   PRSURF=0
                RUPREL=0.
          ENDIF
        ELSE
     IF((UGCONT(L).EQ.K).OR.NOSECON.OR.(.NOT.VAULT))  THEN
                TEMP=TSURF+SURF+UGCONFR*RUPREL
            CALL CLENUP(TEMP)
    TSURF=0
    SURF=0
   TPRSURF=0
   PRSURF=0
            RUPREL=(1-UGCONFR)*RUPREL
         UGRUPT=RUPREL+UGRUPT
          ELSE
    RUPREL=RUPREL+TSURF+SURF
           CALL CLENUP(RUPREL)
    TSURF=0
    SURF=0
   TPRSURF=0
   PRSURF=0
                RUPREL=0.
          ENDIF
    ENDIF
     TKVOL(L)=TKVOL(L)+RUPREL
    MONREL=RUPREL+MONREL
    DETECT=.FALSE.
        IF  (((MAX(DETTIME,TREMDT))-TREMDT).NE.0)  THEN
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            TREMDT=DETTIME
            TREMRT=RPTKRT(L)
         ENDIF
        IF(YRO.NE.0.AND.IYRNUM.LT.YRO)TANKREP=.TRUE.
       CALL FIX(DLAB,K,YR,L,2)
       CALL FIX(DLAB,K,YR,L,1)
     CALL VAPZERO(3,1)
      DO 817 LL=1,NPI
      IF(WLDEFVL(LL).GT.0)  CALL FIX(DLAB,K,YR,LL,7)
      IF(GKDEFVL(LL).GT.0)  CALL FIX(DLAB,K,YR,LL,8)
          IF(RPWLVOL(LL).GT.0)  CALL FIX(DLAB,K,YR,LL,10)
       CALL FIX(DLAB,K,YR,LL,9)
       817 CONTINUE
      IF(TKDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,3)
   ENDIF
 106 CONTINUE
    RUPREL=0
    5223 CONTINUE
   DO 53 L=1,NPI
*   WELDED FLANGE INSTALLATION DEFICEINCY.
      IF(WLDDEF(L).EQ.K)THEN
      ITYPFLG=1040+L
         IF(WLDEFVL(L).EQ.0)THEN
         FALNUM=FALNUM+1
         FALNUM1(FALNUM)=ITYPFLG
         FALNUM7(FALNUM)=(YR-1)*12+K
**    NOT A CONTINUOUS LEAK
             ONGO=.FALSE.
            CALL LEAKRT(ONGO,4,L,0,LKRATE,DM,WLDFWID(L),WLDFLEN(L))
            WLDEFRT(L)=LKRATE
         ENDIF
         DETECT=.FALSE.
      IF(MONMETH(2).AND.VAULT)THEN
      DLAB='IS'
******    INTERSTITIAL MONITORING
 INTERST(L-1+1/L-L/5,2)=FNB(INTERST(
+L-1+1/L-L/5,1))
    IF(INTERST(L-1+1/L-L/5,2).EQ.0)THEN
           DETTIME=FNU(60.,720.)
            DETECT=.TRUE.
        GO TO 7
         ENDIF
      ENDIF
         IF(AGTANK)THEN
             TMIN=30.
       IF(L.EQ.1)THEN
             T2=CONTVOL(L)/FLOWRT(L)
       IF(CONT)THEN
          T2=(24-OPHRSDY)*60.
          IF(T2.LT.(4.*60.))T2=4.*60.
        ENDIF
       ELSE
             T2=MINMO
          IF(WEEKINS)T2=10080.
       IF(CONT)THEN
          T2=(24-OPHRSDY)*60.
          IF(T2.LT.(4.*60.))T2=4.*60.
        ENDIF
       ENDIF
             T1=T2
           CALL RATEDET(WLDEFRT(L),TMIN,T1,T2,DETECT,DETTIME)
    IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
           DLAB='RD'
 IF((CONT.AND.STORAGE).AND.(DETTIME.GT.(OPLEV*TNKCAP(INT(
+ L-1+1/L-L/5))
+/WLDEFRT(L))))DETTIME=OPLEV*TNKCAP(L-1+1/L-L/5)
+/WLDEFRT(L)
 IF(DETTIME.GT.(TNKCAP(L-1+1/L-L/5)/WLDEFRT(L)))
+ DETTIME=TNKCAP(L-1+1/L-L/5)/WLDEFRT(L)
            IF(DETECT) GO TO 7
            IF(INVCNTL)THEN
            CALL IMMINV(4,L,WLDEFRT(L),DETECT,DETTIME)
            DLAB='II'
            IF(DETECT) GO TO 7
            ENDIF
            IF(MONMETH(5))THEN
              DLAB='VW'
               IF((AGCONT(L).EQ.K).OR.NOSECON)THEN
                IF(.NOT.VAPFLG)THEN
                IF(WGDFVAP(L).EQ.O.)THEN
                     CALL VAPOR(3,WGDFVAP(L),DETECT)
                   IF(.NOT.DETECT) VAPFLG=.TRUE.
              WLDFSPH(L)=.0313*POR*VAPWDIS(3)**3
                  ENDIF
                  IF(.NOT.VAPFLG) THEN
                    SPHTIME=WLDFSPH(L)/WLDEFRT(L)
     IF((VTIME(3)*WLDEFRT(L)).GT.WLDFSPH(L).AND.MAX(SPHTIME,
+       WGDFVAP(L)).EQ.WGDFVAP(L)) THEN
                     IF(WGDFVAP(L).GT.43200.) THEN
                         WGDFVAP(L)=WGDFVAP(L)-43200.
                         DETECT=.FALSE.
                        ELSE
                         DETECT=.TRUE.
                         DETTIME=WGDFVAP(L)+1440
                         VAPDET=.TRUE.
                       ENDIF
                       WLDFSPH(L)=WLDFSPH(L)-MINMO*WLDEFRT(L)
         ELSE
            DETECT=.FALSE.
            IF(SPHTIME.LT.MINMO)THEN
              DETECT=.TRUE.
              DETTIME=SPHTIME+1440
              VAPDET=.TRUE.
            ELSE
              DETECT=.FALSE.
              WLDFSPH(L)=WLDFSPH(L)-MINMO*WLDEFRT(L)
              WGDFVAP(L)=WGDFVAP(L)-43200
            ENDIF
         ENDIF
                     ENDIF
                     ENDIF
                  IF(DETECT)GO TO 7
               ENDIF
            ENDIF
```

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34750            ELSE
34755*             UGTANK
34760        IF(IGTANK)THEN
34765              TMIN=30.
34770              T2=MINMO
34775           IF(WEEKINS)T2=10080.
34780        IF(CONT)THEN
34785           T2=(24-OPHRSDY)*60.
34790           IF(T2.LT.(4.*60.))T2=4.*60.
34795         ENDIF
34800              T1=T2
34805         CALL RATEDET(WLDEFRT(L),TMIN,T1,T2,DETECT,DETTIME)
34810     IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
34815            DLAB='RD'
34820 IF((CONT.AND.STORAGE).AND.(DETTIME.GT.(OPLEV*TNKCAP(INT(
34825+L-1+1/L-L/5))
34830+/WLDEFRT(L))))DETTIME=OPLEV*TNKCAP(L-1+1/L-L/5)
34835+/WLDEFRT(L)
34840 IF(DETTIME.GT.(TNKCAP(L-1+1/L-L/5)/WLDEFRT(L)))
34845+  DETTIME=TNKCAP(L-1+1/L-L/5)/WLDEFRT(L)
34850          IF(DETECT) GO TO 7
34855        ENDIF
34860             IF(INVCNTL)THEN
34865             CALL IMMINV(4,L,WLDEFRT(L),DETECT,DETTIME)
34870             DLAB='II'
34875             IF(DETECT) GO TO 7
34880             ENDIF
34885             IF(MONMETH(5))THEN
34890               DLAB='VW'
34895                IF((UGCONT(L).EQ.K).OR.NOSECON)THEN
34900                 IF(.NOT.VAPFLG)THEN
34905                 IF(WGDFVAP(L).EQ.0.)THEN
34910                      CALL VAPOR(3,WGDFVAP(L),DETECT)
34915                    IF(.NOT.DETECT) VAPFLG=.TRUE.
34920               WLDFSPH(L)=.0313*POR*VAPWDIS(3)**3
34925                   ENDIF
34930                   IF(.NOT.VAPFLG) THEN
34935                     SPHTIME=WLDFSPH(L)/WLDEFRT(L)
34940      IF((VTIME(3)*WLDEFRT(L)).GT.WLDFSPH(L).AND.MAX(SPHTIME,
34945+       WGDFVAP(L)).EQ.WGDFVAP(L)) THEN
34950                      IF(WGDFVAP(L).GT.43200.) THEN
34955                          WGDFVAP(L)=WGDFVAP(L)-43200.
34960                          DETECT=.FALSE.
34965                         ELSE
34970                          DETECT=.TRUE.
34975                          DETTIME=WGDFVAP(L)+1440
34980                          VAPDET=.TRUE.
34985                        ENDIF
34990                        WLDFSPH(L)=WLDFSPH(L)-MINMO*WLDEFRT(L)
34995          ELSE
35000             DETECT=.FALSE.
35005             IF(SPHTIME.LT.MINMO)THEN
35010               DETECT=.TRUE.
35015               DETTIME=SPHTIME+1440
35020               VAPDET=.TRUE.
35025             ELSE
35030               DETECT=.FALSE.
```

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              WLDFSPH(L)=WLDFSPH(L)-MINMO*WLDEFRT(L)
              WGDFVAP(L)=WGDFVAP(L)-43200
            ENDIF
         ENDIF
                     ENDIF
                     ENDIF
                  IF(DETECT) GO TO 7
               ENDIF
             ENDIF
         ENDIF
              IF(WLDEFVL(L).EQ.0)THEN
           MOFRAC=FNU(0.,1.)
  IF(((L.EQ.1).AND.(FRACTUG.GE..5)).OR.((L.EQ.1).AND.AGTANK
+ .AND.(HORIZ.OR.(VERT.AND.(TNKCAP(L-1+1/L-L/5
+).LE.1000)))))THEN
       WLDEFVL(L)=WLDEFRT(L)*DAYMO*FILLFR(L)*MOFRAC*FILLTIM(L)
      IF(((MAX((WLDEFVL(L)/WLDEFRT(L)),TREMDT))-TREMDT).NE.0)  THEN
               TREMDT=WLDEFVL(L)/WLDEFRT(L)
               TREMRT=WLDEFRT(L)
             ENDIF
             ELSE
  WLDEFVL(L)=WLDEFRT(L)*MINMO*MOFRAC*TANKTIM(
+L-1+1/L-L/5)
      IF(((MAX((WLDEFVL(L)/WLDEFRT(L)),TREMDT))-TREMDT).NE.0)  THEN
               TREMDT=WLDEFVL(L)/WLDEFRT(L)
               TREMRT=WLDEFRT(L)
             ENDIF
             ENDIF
       IF(WLDEFVL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))
+      WLDEFVL(L)=FILLVOL(1)*FILLFR(1)*30.
             ELSE
        IF(((L.EQ.1).AND.(FRACTUG.GE..5)).OR.((L.EQ.1).AND.AGTANK
+ .AND.(HORIZ.OR.(VERT.AND.(TNKCAP(L-1+1/L-L/5
+).LE.1000)))))THEN
          WLDEFVL(L)=WLDEFRT(L)*DAYMO*FILLFR(L)*FILLTIM(L)
      IF(((MAX((WLDEFVL(L)/WLDEFRT(L)),TREMDT))-TREMDT).NE.0)  THEN
              TREMDT=WLDEFVL(L)/WLDEFRT(L)
              TREMRT=WLDEFRT(L)
            ENDIF
            ELSE
WLDEFVL(L)=WLDEFRT(L)*MINMO*TANKTIM(L-1+1/L-L/5
+)
     IF(((MAX((WLDEFVL(L)/WLDEFRT(L)),TREMDT))-TREMDT).NE.0)  THEN
              TREMDT=WLDEFVL(L)/WLDEFRT(L)
              TREMRT=WLDEFRT(L)
            ENDIF
            ENDIF
      IF(WLDEFVL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))
+     WLDEFVL(L)=FILLVOL(1)*FILLFR(1)*30.
             ENDIF
        IF(AGTANK)THEN
     IF(PIPCONT(L).EQ.K)THEN
              TSURF=PAGFRAC*WLDEFVL(L)+TSURF
              TSUB=(1-PAGFRAC)*WLDEFVL(L)+TSUB
      WLVOL(L)=WLVOL(L)+WLDEFVL(L)*(1-PAGFRAC)
             ELSE
              TSURF=WLDEFVL(L)+TSURF
              ENDIF
         ELSEIF(IGTANK)THEN
            IF(PIPCONT(L).EQ.K)THEN
               TSURF=PAGFRAC*WLDEFVL(L)+TSURF
               TSUB=(1-PAGFRAC)*WLDEFVL(L)+TSUB
               WLVOL(L)=WLVOL(L)+WLDEFVL(L)*(1-PAGFRAC)
             ELSE
               TSURF=WLDEFVL(L)+TSURF
             ENDIF
             ELSE
*               UGTANK
              IF(VAULT)THEN
        IF(UGCONT(L-1+1/L-L/5).EQ.K)THEN
                  TSURF=UGCONFR*WLDEFVL(L)+TSURF
                  TSUB=(1-UGCONFR)*WLDEFVL(L)+TSUB
        WLVOL(L)=WLVOL(L)+WLDEFVL(L)*(1-UGCONFR)
                 ELSE
                  TSURF=WLDEFVL(L)+TSURF
             ENDIF
             ELSE
               TSUB=WLDEFVL(L)+TSUB
        WLVOL(L)=WLVOL(L)+WLDEFVL(L)
             ENDIF
            ENDIF
         DO 1009 II=FALNUM,1,-1
           IF(FALNUM1(II).EQ.ITYPFLG)  THEN
             IF(FALNUM7(II).EQ.((YR-1)*12+K))THEN
              FALNUM2(II)=WLDEFVL(L)
              FALNUM5(II)=MOFRAC*720
             ELSE
             FALNUM2(II)=FALNUM2(II)+WLDEFVL(L)
              FALNUM5(II)=FALNUM5(II)+720
             ENDIF
             GO TO 1010
           ENDIF
           1009 CONTINUE
           1010 CONTINUE
            FALNUM3(II)=((YR-1)*12)+K
            GO TO 8
  7      DEFREL=WLDEFRT(L)*DETTIME
IF((L.EQ.1).AND.(.NOT.((AGTANK.AND.VERT.AND.(TNKCAP(1)
+    .GT.1000))).OR.(IGTANK.AND.(FRACTUG.LT..5))))THEN
    IF(DEFREL.GT.(FILLVOL(1)*FILLFR(1)*DAYMO))DEFREL=
+         FILLVOL(1)*FILLFR(1)*DAYMO
ELSEIF((L.NE.1).AND.(.NOT.((IGTANK.AND.(FRACTUG.LT..5))
+    .OR.AGTANK)))THEN
    IF(DEFREL.GT.(FILLVOL(1)*FILLFR(1)*DAYMO))DEFREL=
+         FILLVOL(1)*FILLFR(1)*DAYMO
ELSE
IF(DEFREL.GT.(TNKCAP(L-1+1/L-L/5)*OPLEV))THEN
             DEFREL=TNKCAP(L-1+1/L-L/5)*OPLEV
         ENDIF
ENDIF
         DO 1011 II=FALNUM,1,-1
           IF(FALNUM1(II).EQ.ITYPFLG)THEN
             FALNUM2(II)=FALNUM2(II)+DEFREL
             FALNUM5(II)=FALNUM5(II)+DETTIME/60.
            GO TO 1012
          ENDIF
          1011 CONTINUE
          1012 CONTINUE
          FALNUM3(II)=((YR-1)*12)+K
          IF (AGTANK) THEN
  IF (PIPCONT(L).EQ.K)  THEN
             TEMP=TSURF+SURF+PAGFRAC*DEFREL
           CALL CLENUP(TEMP)
    TSURF=0
    SURF=0
  TPRSURF=0
  PRSURF=0
           DEFREL=(1-PAGFRAC)*DEFREL
       AGRUPT=DEFREL+AGRUPT
        ELSE
       DEFREL=DEFREL+TSURF+SURF
         CALL CLENUP(DEFREL)
    TSURF=0
    SURF=0
  TPRSURF=0
  PRSURF=0
             DEFREL=0.
        ENDIF
     ELSEIF(IGTANK) THEN
         IF(PIPCONT(L).EQ.K) THEN
          TEMP=TSURF+SURF+PAGFRAC*DEFREL
          CALL CLENUP(TEMP)
          TSURF=0
          SURF=0
          TPRSURF=0
          PRSURF=0
         DEFREL=(1-PAGFRAC)*DEFREL
          UGRUPT=DEFREL+UGRUPT
         ELSE
          DEFREL=DEFREL+TSURF+SURF
          CALL CLENUP(DEFREL)
          TSURF=0
          SURF=0
          TPRSURF=0
          PRSURF=0
          DEFREL=0
         ENDIF
      ELSE
IF((UGCONT(L-1+1/L-L/5).EQ.K).OR.NOSECON) THEN
                  TEMP=TSURF+SURF+UGCONFR*DEFREL
          CALL CLENUP(TEMP)
    TSURF=0
    SURF=0
  TPRSURF=0
  PRSURF=0
          DEFREL=(1-UGCONFR)*DEFREL
       UGRUPT=DEFREL+UGRUPT
        ELSE
       DEFREL=DEFREL+TSURF+SURF
         CALL CLENUP(DEFREL)
    TSURF=0
```

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35890      SURF=0
35895     TPRSURF=0
35900     PRSURF=0
35905                  DEFREL=0.
35910           ENDIF
35915           ENDIF
35920        WLVOL(L)=WLVOL(L)+DEFREL
35925           MONREL=DEFREL+MONREL
35930           DETECT=.FALSE.
35935          IF  (((MAX(DETTIME,TREMDT))-TREMDT).NE.0)  THEN
35940             TREMDT=DETTIME
35945             TREMRT=WLDEFRT(L)
35950          ENDIF
35955        CALL  FIX(DLAB,K,YR,L,7)
35960      CALL VAPZERO(4,L)
35965          IF(RPWLVOL(L).GT.0)  CALL  FIX(DLAB,K,YR,L,10)
35970  8   CONTINUE
35975     ENDIF
35980        DEFREL=0
35985 53   CONTINUE
35990      DO 54 L=1,NPI
35995*   GASKETED FLANGE INSTALLATION DEFICEINCY.
36000 IF(GSKDEF(L).EQ.K)THEN
36005      ITYPFLG=1050+L
36010          IF(GKDEFVL(L).EQ.0)THEN
36015          FALNUM=FALNUM+1
36020          FALNUM1(FALNUM)=ITYPFLG
36025          FALNUM7(FALNUM)=(YR-1)*12+K
36030**    NOT A CONTINUOUS LEAK
36035              ONGO=.FALSE.
36040             CALL  LEAKRT(ONGO,5,L,0,LKRATE,DM,GKDFWID(L),GKDFLEN(L))
36045             GKDEFRT(L)=LKRATE
36050          ENDIF
36055          DETECT=.FALSE.
36060          IF(AGTANK)THEN
36065              TMIN=30.
36070        IF(L.EQ.1)THEN
36075              T2=CONTVOL(L)/FLOWRT(L)
36080        IF(CONT)THEN
36085           T2=(24-OPHRSDY)*60.
36090           IF(T2.LT.(4.*60.))T2=4.*60.
36095         ENDIF
36100        ELSE
36105              T2=MINMO
36110           IF(WEEKINS)T2=10080.
36115        IF(CONT)THEN
36120           T2=(24-OPHRSDY)*60.
36125           IF(T2.LT.(4.*60.))T2=4.*60.
36130         ENDIF
36135        ENDIF
36140              T1=T2
36145            CALL  RATEDET(GKDEFRT(L),TMIN,T1,T2,DETECT,DETTIME)
36150     IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
36155              DLAB='RD'
36160 IF((CONT.AND.STORAGE).AND.(DETTIME.GT.(OPLEV*TNKCAP(
36165+L-1+1/L-L/5)/GKDEFRT(L)
36170+)))DETTIME=OPLEV*TNKCAP(L-1+1/L-L/5)/GKDEFRT(L)
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36175 IF(DETTIME.GT.(TNKCAP(L-1+1/L-L/5)/GKDEFRT(L)))
36180+     DETTIME=TNKCAP(L-1+1/L-L/5)/GKDEFRT(L)
36185           IF(DETECT) GO TO 107
36190           IF(INVCNTL)THEN
36195           CALL  IMMINV(5,L,GKDEFRT(L),DETECT,DETTIME)
36200           DLAB='II'
36205           IF(DETECT) GO TO 107
36210           ENDIF
36215           IF(MONMETH(5))THEN
36220             DLAB='VW'
36225 IF((AGCONT(L-1+1/L-L/5).EQ.K).OR.NOSECON)THEN
36230               IF(.NOT.VAPFLG)THEN
36235               IF(WGDFVAP(L).EQ.O.)THEN
36240                    CALL  VAPOR(3,WGDFVAP(L),DETECT)
36245                  IF(.NOT.DETECT)  VAPFLG=.TRUE.
36250             GKDFSPH(L)=.0313*POR*VAPWDIS(3)**3
36255                 ENDIF
36260                 IF(.NOT.VAPFLG)  THEN
36265                   SPHTIME=GKDFSPH(L)/GKDEFRT(L)
36270    IF((VTIME(3)*GKDEFRT(L)).GT.GKDFSPH(L).AND.MAX(SPHTIME,
36275+      WGDFVAP(L)).EQ.WGDFVAP(L))  THEN
36280                    IF(WGDFVAP(L).GT.43200.)  THEN
36285                        WGDFVAP(L)=WGDFVAP(L)-43200.
36290                        DETECT=.FALSE.
36295                       ELSE
36300                        DETECT=.TRUE.
36305                        DETTIME=WGDFVAP(L)+1440
36310                        VAPDET=.TRUE.
36315                      ENDIF
36320                      GKDFSPH(L)=GKDFSPH(L)-MINMO*GKDEFRT(L)
36325        ELSE
36330           DETECT=.FALSE.
36335           IF(SPHTIME.LT.MINMO)THEN
36340             DETECT=.TRUE.
36345             DETTIME=SPHTIME+1440
36350             VAPDET=.TRUE.
36355           ELSE
36360             DETECT=.FALSE.
36365             GKDFSPH(L)=GKDFSPH(L)-MINMO*GKDEFRT(L)
36370             WGDFVAP(L)=WGDFVAP(L)-43200
36375           ENDIF
36380        ENDIF
36385                   ENDIF
36390                   ENDIF
36395                IF(DETECT)GO TO 107
36400             ENDIF
36405          ENDIF
36410         ELSE
36415*          UGTANK.OR.IGTANK
36420           IF(VAULT)THEN
36425     IF(MONMETH(2).AND.VAULT)THEN
36430     DLAB='IS'
36435******     INTERSTITIAL MONITORING
36440  INTERST(L-1+1/L-L/5,2)=FNB(INTERST(
36445+L-1+1/L-L/5,1))
36450        IF(INTERST(L-1+1/L-L/5,2).EQ.O)THEN
36455           IF(VAULT)THEN
```

```
36460                     DETTIME=FNU(5./GKDEFRT(L),MINMO)
36465                ELSE
36470                 DETTIME=FNU(60.,720.)
36475               ENDIF
36480              DETECT=.TRUE.
36485           GO TO 107
36490           ENDIF
36495        ENDIF
36500               ENDIF
36505         IF(IGTANK)THEN
36510              TMIN=30.
36515              T2=MINMO
36520            IF(WEEKINS)T2=10080.
36525         IF(CONT)THEN
36530            T2=(24-OPHRSDY)*60.
36535            IF(T2.LT.(4.*60.))T2=4.*60.
36540          ENDIF
36545               T1=T2
36550          CALL RATEDET(GKDEFRT(L),TMIN,T1,T2,DETECT,DETTIME)
36555     IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
36560              DLAB='RD'
36565 IF((CONT.AND.STORAGE).AND.(DETTIME.GT.(OPLEV*TNKCAP(INT(
36570+L-1+1/L-L/5))/GKDEFRT(L)
36575+)))DETTIME=OPLEV*TNKCAP(L-1+1/L-L/5)/GKDEFRT(L)
36580 IF(DETTIME.GT.(TNKCAP(L-1+1/L-L/5)/GKDEFRT(L)))
36585+  DETTIME=TNKCAP(L-1+1/L-L/5)/GKDEFRT(L)
36590            IF(DETECT) GO TO 107
36595         ENDIF
36600              IF(INVCNTL)THEN
36605              CALL IMM!NV(5,L,GKDEFRT(L),DETECT,DETTIME)
36610              DLAB='II'
36615              IF(DETECT) GO TO 107
36620              ENDIF
36625              IF(MONMETH(5))THEN
36630                DLAB='VW'
36635 IF((UGCONT(L-1+1/L-L/5).EQ.K).OR.NOSECON)THEN
36640                   IF(.NOT.VAPFLG)THEN
36645                   IF(WGDFVAP(L).EQ.0.)THEN
36650                        CALL VAPOR(3,WGDFVAP(L),DETECT)
36655                      IF(.NOT.DETECT) VAPFLG=.TRUE.
36660                 GKDFSPH(L)=.0313*POR*VAPWDIS(3)**3
36665                     ENDIF
36670                     IF(.NOT.VAPFLG) THEN
36675                       SPHTIME=GKDFSPH(L)/GKDEFRT(L)
36680      IF((VTIME(3)*GKDEFRT(L)).GT.GKDFSPH(L).AND.MAX(SPHTIME,
36685+          WGDFVAP(L)).EQ.WGDFVAP(L))  THEN
36690                        IF(WGDFVAP(L).GT.43200.)  THEN
36695                            WGDFVAP(L)=WGDFVAP(L)-43200.
36700                            DETECT=.FALSE.
36705                          ELSE
36710                            DETECT=.TRUE.
36715                            DETTIME=WGDFVAP(L)+1440
36720                            VAPDET=.TRUE.
36725                          ENDIF
36730                          GKDFSPH(L)=GKDFSPH(L)-MINMO*GKDEFRT(L)
36735           ELSE
36740              DETECT=.FALSE.
```

```
            IF (SPHTIME.LT.MINMO) THEN
              DETECT=.TRUE.
              DETTIME=SPHTIME+1440
              VAPDET=.TRUE.
            ELSE
              DETECT=.FALSE.
              GKDFSPH (L) =GKDFSPH (L) -MINMO*GKDEFRT (L)
              WGDFVAP (L) =WGDFVAP (L) -43200
            ENDIF
         ENDIF
                      ENDIF
                      ENDIF
                   IF (DETECT) GO TO 107
                ENDIF
              ENDIF
         ENDIF
         IF (GKDEFVL (L) .EQ.0) THEN
           MOFRAC=FNU (0.,1.)
        IF (((L.EQ.1) .AND. (FRACTUG.GE..5)) .OR. ((L.EQ.1) .AND.AGTANK
+ .AND. (HORIZ.OR. (VERT.AND. (TNKCAP (L-1+1/L-L/5
+) .LE.1000))))) THEN
     GKDEFVL (L) =GKDEFRT (L) *DAYMO*FILLFR (L) *MOFRAC*FILLTIM (L)
      IF (((MAX ((GKDEFVL (L) /GKDEFRT (L)) ,TREMDT)) -TREMDT) .NE.0)  THEN
               TREMDT=GKDEFVL (L) /GKDEFRT (L)
               TREMRT=GKDEFRT (L)
             ENDIF
             ELSE
GKDEFVL (L) =GKDEFRT (L) *MINMO*MOFRAC*TANKTIM (
+L-1+1/L-L/5)
      IF (((MAX ((GKDEFVL (L) /GKDEFRT (L)) ,TREMDT)) -TREMDT) .NE.0)  THEN
               TREMDT=GKDEFVL (L) /GKDEFRT (L)
               TREMRT=GKDEFRT (L)
             ENDIF
             ENDIF
       IF (GKDEFVL (L) .GT. (FILLVOL (1) *FILLFR (1) *30.))
+      GKDEFVL (L) =FILLVOL (1) *FILLFR (1) *30.
              ELSE
IF (((L.EQ.1) .AND. (FRACTUG.GE..5)) .OR. ((L.EQ.1) .AND.AGTANK
+ .AND. (HORIZ.OR. (VERT.AND. (TNKCAP (L-1+1/L-L/5
+) .LE.1000))))) THEN
      GKDEFVL (L) =GKDEFRT (L) *DAYMO*FILLFR (L) *FILLTIM (L)
      IF (((MAX ((GKDEFVL (L) /GKDEFRT (L)) ,TREMDT)) -TREMDT) .NE.0)  THEN
               TREMDT=GKDEFVL (L) /GKDEFRT (L)
               TREMRT=GKDEFRT (L)
             ENDIF
             ELSE
GKDEFVL (L) =GKDEFRT (L) *MINMO*TANKTIM (L-1+1/L-L/5
+)
      IF (((MAX ((GKDEFVL (L) /GKDEFRT (L)) ,TREMDT)) -TREMDT) .NE.0)  THEN
               TREMDT=GKDEFVL (L) /GKDEFRT (L)
               TREMRT=GKDEFRT (L)
             ENDIF
             ENDIF
       IF (GKDEFVL (L) .GT. (FILLVOL (1) *FILLFR (1) *30.))
+      GKDEFVL (L) =FILLVOL (1) *FILLFR (1) *30.
        ENDIF
         IF (AGTANK) THEN
```

```
37030           IF (PIPCONT (L) .EQ.K) THEN
37035                     TSURF=PAGFRAC*GKDEFVL (L) +TSURF
37040                     TSUB= (1-PAGFRAC) *GKDEFVL (L) +TSUB
37045              GKVOL (L) =GKVOL (L) +GKDEFVL (L) * (1-PAGFRAC)
37050                    ELSE
37055                     TSURF=GKDEFVL (L) +TSURF
37060                 ENDIF
37065          ELSEIF (IGTANK) THEN
37070              IF (PIPCONT (L) .EQ.K) THEN
37075                  TSURF=PAGFRAC*GKDEFVL (L) +TSURF
37080                  TSUB= (1-PAGFRAC) *GKDEFVL (L) +TSUB
37085                  GKVOL (L) =GKVOL (L) +GKDEFVL (L) * (1-PAGFRAC)
37090               ELSE
37095                  TSURF=GKDEFVL (L) +TSURF
37100               ENDIF
37105               ELSE
37110*                  UGTANK
37115                IF (VAULT) THEN
37120         IF (UGCONT (L-1+1/L-L/5) .EQ.K) THEN
37125                      TSURF=UGCONFR*GKDEFVL (L) +TSURF
37130                      TSUB= (1-UGCONFR) *GKDEFVL (L) +TSUB
37135              GKVOL (L) =GKVOL (L) +GKDEFVL (L) * (1-UGCONFR)
37140                     ELSE
37145                      TSURF=GKDEFVL (L) +TSURF
37150               ENDIF
37155               ELSE
37160                  TSUB=GKDEFVL (L) +TSUB
37165              GKVOL (L) =GKVOL (L) +GKDEFVL (L)
37170               ENDIF
37175              ENDIF
37180        DO 1013 II=FALNUM,1,-1
37185              IF (FALNUM1 (II) .EQ.ITYPFLG)  THEN
37190               IF (FALNUM7 (II) .EQ. ((YR-1) *12+K)) THEN
37195                 FALNUM2 (II) =GKDEFVL (L)
37200                 FALNUM5 (II) =MOFRAC*720
37205               ELSE
37210                FALNUM2 (II) =FALNUM2 (II) +GKDEFVL (L)
37215                FALNUM5 (II) =FALNUM5 (II) +720
37220               ENDIF
37225               GO TO 1014
37230            ENDIF
37235            1013 CONTINUE
37240            1014 CONTINUE
37245              FALNUM3 (II) = ((YR-1) *12) +K
37250              GO TO 108
37255  107         DEFREL=GKDEFRT (L) *DETTIME
37260 IF ((L.EQ.1) .AND. (.NOT. ((AGTANK.AND.VERT.AND. (TNKCAP (1)
37265+   .GT.1000))) .OR. (IGTANK.AND. (FRACTUG.LT..5)))) THEN
37270     IF (DEFREL.GT. (FILLVOL (1) *FILLFR (1) *DAYMO)) DEFREL=
37275+           FILLVOL (1) *FILLFR (1) *DAYMO
37280 ELSEIF ((L.NE.1) .AND. (.NOT. ((IGTANK.AND. (FRACTUG.LT..5))
37285+   .OR.AGTANK))) THEN
37290     IF (DEFREL.GT. (FILLVOL (1) *FILLFR (1) *DAYMO)) DEFREL=
37295+           FILLVOL (1) *FILLFR (1) *DAYMO
37300 ELSE
37305 IF (DEFREL.GT. (TNKCAP (L-1+1/L-L/5) *OPLEV)) THEN
37310                 DEFREL=TNKCAP (L-1+1/L-L/5) *OPLEV
```

```
        ENDIF
ENDIF
        DO 1015 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.ITYPFLG) THEN
            FALNUM2(II)=FALNUM2(II)+DEFREL
            FALNUM5(II)=FALNUM5(II)+DETTIME/60.
            GO TO 1016
          ENDIF
          1015 CONTINUE
          1016 CONTINUE
          FALNUM3(II)=((YR-1)*12)+K
          IF(AGTANK) THEN
         IF(PIPCONT(L).EQ.K)  THEN
               TEMP=TSURF+SURF+PAGFRAC*DEFREL
           CALL CLENUP(TEMP)
     TSURF=0
     SURF=0
   TPRSURF=0
   PRSURF=0
           DEFREL=(1-PAGFRAC)*DEFREL
        AGRUPT=DEFREL+AGRUPT
         ELSE
        DEFREL=DEFREL+TSURF+SURF
          CALL CLENUP(DEFREL)
     TSURF=0
     SURF=0
   TPRSURF=0
   PRSURF=0
              DEFREL=0.
         ENDIF
      ELSEIF(IGTANK) THEN
          IF(PIPCONT(L).EQ.K) THEN
           TEMP=TSURF+SURF+PAGFRAC*DEFREL
           CALL CLENUP(TEMP)
           TSURF=0
           SURF=0
           TPRSURF=0
           PRSURF=0
          DEFREL=(1-PAGFRAC)*DEFREL
           UGRUPT=DEFREL+UGRUPT
          ELSE
           DEFREL=DEFREL+TSURF+SURF
           CALL CLENUP(DEFREL)
           TSURF=0
           SURF=0
           TPRSURF=0
           PRSURF=0
           DEFREL=0
          ENDIF
       ELSE
IF((UGCONT(L-1+1/L-L/5).EQ.K).OR.NOSECON) THEN
                 TEMP=TSURF+SURF+UGCONFR*DEFREL
           CALL CLENUP(TEMP)
     TSURF=0
     SURF=0
   TPRSURF=0
   PRSURF=0
```

```
            DEFREL=(1-UGCONFR)*DEFREL
         UGRUPT=DEFREL+UGRUPT
          ELSE
         DEFREL=DEFREL+TSURF+SURF
           CALL CLENUP(DEFREL)
      TSURF=0
      SURF=0
    TPRSURF=0
    PRSURF=0
             DEFREL=0.
         ENDIF
         ENDIF
         GKVOL(L)=GKVOL(L)+DEFREL
         MONREL=DEFREL+MONREL
         DETECT=.FALSE.
        IF (((MAX(DETTIME,TREMDT))-TREMDT).NE.0) THEN
           TREMDT=DETTIME
           TREMRT=GKDEFRT(L)
        ENDIF
      CALL FIX(DLAB,K,YR,L,8)
      CALL FIX(DLAB,K,YR,L,9)
   CALL VAPZERO(5,L)
 108   CONTINUE
        ENDIF
      DEFREL=0
     54 CONTINUE
     DO 55 L=1,NPI
*      WELDED FLANGE RUPTURE
        IF(RUPWLD(L).EQ.K)THEN
     ITYPFLG=2040+L
****       NOT A CONTINUOUS LEAK
           IF(RPWLVOL(L).EQ.0)THEN
        FALNUM=FALNUM+1
        FALNUM1(FALNUM)=ITYPFLG
        FALNUM7(FALNUM)=(YR-1)*12+K
              ONGO=.FALSE.
       CALL LEAKRT(ONGO,4,L,0,LKRATE,DM,RPWLWID(L),RPWLLEN(L))
              RPWLRT(L)=LKRATE
           ENDIF
           DETECT=.FALSE.
     IF(MONMETH(2).AND.VAULT)THEN
     DLAB='IS'
******     INTERSTITIAL MONITORING
  INTERST(L-1+1/L-L/5,2)=FNB(INTERST(
+L-1+1/L-L/5,1))
         IF(INTERST(L-1+1/L-L/5,2).EQ.0)THEN
           DETTIME=FNU(60.,720.)
            DETECT=.TRUE.
       GO TO 11
        ENDIF
     ENDIF
            IF(AGTANK)THEN
            TMIN=30.
      IF(L.EQ.1)THEN
            T2=CONTVOL(L)/FLOWRT(L)
      IF(CONT)THEN
         T2=(24-OPHRSDY)*60.
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```
           IF(T2.LT.(4.*60.))T2=4.*60.
         ENDIF
        ELSE
              T2=MINMO
           IF(WEEKINS)T2=10080.
        IF(CONT)THEN
           T2=(24-OPHRSDY)*60.
           IF(T2.LT.(4.*60.))T2=4.*60.
         ENDIF
       ENDIF
              T1=T2
               CALL RATEDET(RPWLRT(L),TMIN,T1,T2,DETECT,DETTIME)
    IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
            DLAB='RD'
                IF(DETECT) GO TO 11
                IF(INVCNTL)THEN
                CALL IMMINV(4,L,RPWLRT(L),DETECT,DETTIME)
             DLAB='II'
                IF(DETECT) GO TO 11
                ENDIF
                IF(MONMETH(5))THEN
               DLAB='VW'
IF((AGCONT(L-1+1/L-L/5).EQ.K).OR.NOSECON)THEN
                 IF(.NOT.VAPFLG)THEN
                 IF(WGLRVAP(L).EQ.0.)THEN
                      CALL VAPOR(3,WGLRVAP(L),DETECT)
                    IF(.NOT.DETECT) VAPFLG=.TRUE.
              WLRPSPH(L)=.0313*POR*VAPWDIS(3)**3
                   ENDIF
                   IF(.NOT.VAPFLG) THEN
                     SPHTIME=WLRPSPH(L)/RPWLRT(L)
    IF((VTIME(3)*RPWLRT(L)).GT.WLRPSPH(L).AND.MAX(SPHTIME,
       WGLRVAP(L)).EQ.WGLRVAP(L)) THEN
                      IF(WGLRVAP(L).GT.43200.) THEN
                          WGLRVAP(L)=WGLRVAP(L)-43200.
                          DETECT=.FALSE.
                         ELSE
                          DETECT=.TRUE.
                          DETTIME=WGLRVAP(L)+1440
                          VAPDET=.TRUE.
                        ENDIF
                        WLRPSPH(L)=WLRPSPH(L)-MINMO*RPWLRT(L)
        ELSE
           DETECT=.FALSE.
           IF(SPHTIME.LT.MINMO)THEN
             DETECT=.TRUE.
             DETTIME=SPHTIME+1440
             VAPDET=.TRUE.
           ELSE
             DETECT=.FALSE.
             WLRPSPH(L)=WLRPSPH(L)-MINMO*RPWLRT(L)
             WGLRVAP(L)=WGLRVAP(L)-43200
           ENDIF
        ENDIF
                     ENDIF
                     ENDIF
                     IF(DETECT)GO TO 11
                   ENDIF
                ENDIF
            ELSE
*            UGTANK.OR.IGTANK
       IF(IGTANK)THEN
              TMIN=30.
              T2=MINMO
           IF(WEEKINS)T2=10080.
       IF(CONT)THEN
          T2=(24-OPHRSDY)*60.
          IF(T2.LT.(4.*60.))T2=4.*60.
        ENDIF
             T1=T2
        CALL RATEDET(RPWLRT(L),TMIN,T1,T2,DETECT,DETTIME)
    IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
           DLAB='RD'
IF((CONT.AND.STORAGE).AND.(DETTIME.GT.(OPLEV*TNKCAP(INT(
+L-1+1/L-L/5))/RPWLRT(L)
+)))DETTIME=OPLEV*TNKCAP(L-1+1/L-L/5)/RPWLRT(L)
IF(DETTIME.GT.(TNKCAP(L-1+1/L-L/5)/RPWLRT(L)))
+  DETTIME=TNKCAP(L-1+1/L-L/5)/RPWLRT(L)
         IF(DETECT) GO TO 11
       ENDIF
            IF(INVCNTL)THEN
            CALL IMMINV(4,L,RPWLRT(L),DETECT,DETTIME)
            DLAB='II'
            IF(DETECT) GO TO 11
            ENDIF
            IF(MONMETH(5))THEN
              DLAB='VW'
IF((UGCONT(L-1+1/L-L/5).EQ.K).OR.NOSECON)THEN
                IF(.NOT.VAPFLG)THEN
                IF(WGLRVAP(L).EQ.0.)THEN
                     CALL VAPOR(3,WGLRVAP(L),DETECT)
                   IF(.NOT.DETECT) VAPFLG=.TRUE.
              WLRPSPH(L)=.0313*POR*VAPWDIS(3)**3
                  ENDIF
                  IF(.NOT.VAPFLG) THEN
                    SPHTIME=WLRPSPH(L)/RPWLRT(L)
    IF((VTIME(3)*RPWLRT(L)).GT.WLRPSPH(L).AND.MAX(SPHTIME,
+      WGLRVAP(L)).EQ.WGLRVAP(L)) THEN
                     IF(WGLRVAP(L).GT.43200.) THEN
                         WGLRVAP(L)=WGLRVAP(L)-43200.
                         DETECT=.FALSE.
                        ELSE
                         DETECT=.TRUE.
                         DETTIME=WGLRVAP(L)+1440
                         VAPDET=.TRUE.
                       ENDIF
                       WLRPSPH(L)=WLRPSPH(L)-MINMO*RPWLRT(L)
        ELSE
           DETECT=.FALSE.
           IF(SPHTIME.LT.MINMO)THEN
             DETECT=.TRUE.
             DETTIME=SPHTIME+1440
             VAPDET=.TRUE.
           ELSE
```

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             DETECT=.FALSE.
             WLRPSPH(L)=WLRPSPH(L)-MINMO*RPWLRT(L)
             WGLRVAP(L)=WGLRVAP(L)-43200
           ENDIF
        ENDIF
                   ENDIF
                   ENDIF
                IF(DETECT) GO TO 11
              ENDIF
            ENDIF
           ENDIF
             IF(RPWLVOL(L).EQ.0)THEN
          MOFRAC=FNU(0.,1.)
  IF(((L.EQ.1).AND.(FRACTUG.GE..5)).OR.((L.EQ.1).AND.AGTANK
  .AND.(HORIZ.OR.(VERT.AND.(TNKCAP(L-1+1/L-L/5
).LE.1000)))))THEN
    RPWLVOL(L)=RPWLRT(L)*DAYMO*FILLFR(L)*MOFRAC*FILLTIM(L)
     IF(((MAX((RPWLVOL(L)/RPWLRT(L)),TREMDT))-TREMDT).NE.0) THEN
             TREMDT=RPWLVOL(L)/RPWLRT(L)
             TREMRT=RPWLRT(L)
            ENDIF
            ELSE
 RPWLVOL(L)=RPWLRT(L)*MINMO*MOFRAC*TANKTIM(
L-1+1/L-L/5)
     IF(((MAX((RPWLVOL(L)/RPWLRT(L)),TREMDT))-TREMDT).NE.0) THEN
             TREMDT=RPWLVOL(L)/RPWLRT(L)
             TREMRT=RPWLRT(L)
            ENDIF
            ENDIF
      IF(RPWLVOL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))
      RPWLVOL(L)=FILLVOL(1)*FILLFR(1)*30.
            ELSE
  IF(((L.EQ.1).AND.(FRACTUG.GE..5)).OR.((L.EQ.1).AND.AGTANK.AND.
  (HORIZ.OR.(VERT.AND.(TNKCAP(L-1+1/L-L/5).LE.
1000)))))THEN
       RPWLVOL(L)=RPWLRT(L)*DAYMO*FILLFR(L)*FILLTIM(L)
     IF(((MAX((RPWLVOL(L)/RPWLRT(L)),TREMDT))-TREMDT).NE.0) THEN
             TREMDT=RPWLVOL(L)/RPWLRT(L)
             TREMRT=RPWLRT(L)
           ENDIF
           ELSE
 RPWLVOL(L)=RPWLRT(L)*MINMO*TANKTIM(L-1+1/L-L/5)
     IF(((MAX((RPWLVOL(L)/RPWLRT(L)),TREMDT))-TREMDT).NE.0) THEN
             TREMDT=RPWLVOL(L)/RPWLRT(L)
             TREMRT=RPWLRT(L)
           ENDIF
           ENDIF
      IF(RPWLVOL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))
      RPWLVOL(L)=FILLVOL(1)*FILLFR(1)*30.
            ENDIF
       IF(AGTANK)THEN
          IF(PIPCONT(L).EQ.K)THEN
            TSURF=PAGFRAC*RPWLVOL(L)+TSURF
             TSUB=(1-PAGFRAC)*RPWLVOL(L)+TSUB
        WLVOL(L)=WLVOL(L)+RPWLVOL(L)*(1-PAGFRAC)
               ELSE
             TSURF=RPWLVOL(L)+TSURF
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38740              ENDIF
38745         ELSEIF (IGTANK) THEN
38750             IF (PIPCONT (L) .EQ.K) THEN
38755                TSURF=PAGFRAC*RPWLVOL (L) +TSURF
38760                TSUB= (1-PAGFRAC) *RPWLVOL (L) +TSUB
38765                WLVOL (L) =WLVOL (L) +RPWLVOL (L) * (1-PAGFRAC)
38770              ELSE
38775                TSURF=RPWLVOL (L) +TSURF
38780              ENDIF
38785              ELSE
38790*                 UGTANK
38795               IF (VAULT) THEN
38800               IF (UGCONT (L-1+1/L-L/5) .EQ.K) THEN
38805                    TSURF=UGCONFR*RPWLVOL (L) +TSURF
38810                    TSUB= (1-UGCONFR) *RPWLVOL (L) +TSUB
38815           WLVOL (L) =WLVOL (L) +RPWLVOL (L) * (1-UGCONFR)
38820                   ELSE
38825                    TSURF=RPWLVOL (L) +TSURF
38830               ENDIF
38835               ELSE
38840                  TSUB=RPWLVOL (L) +TSUB
38845           WLVOL (L) =WLVOL (L) +RPWLVOL (L)
38850               ENDIF
38855             ENDIF
38860         DO 1017 II=FALNUM,1,-1
38865            IF (FALNUM1 (II) .EQ.ITYPFLG)  THEN
38870               IF (FALNUM7 (II) .EQ. ((YR-1) *12+K)) THEN
38875                FALNUM2 (II) =RPWLVOL (L)
38880                FALNUM5 (II) =MOFRAC*720
38885               ELSE
38890                FALNUM2 (II) =FALNUM2 (II) +RPWLVOL (L)
38895                FALNUM5 (II) =FALNUM5 (II) +720
38900               ENDIF
38905               GO TO 1018
38910            ENDIF
38915            1017 CONTINUE
38920            1018 CONTINUE
38925             FALNUM3 (II) = ((YR-1) *12) +K
38930               GO TO 12
38935            11     CONTINUE
38940              RUPREL=RPWLRT (L) *DETTIME
38945 IF ((L.EQ.1) .AND. (.NOT. ((AGTANK.AND.VERT.AND. (TNKCAP (1)
38950+    .GT.1000))) .OR. (IGTANK.AND. (FRACTUG.LT..5)))) THEN
38955     IF (RUPREL.GT. (FILLVOL (1) *FILLFR (1) *DAYMO)) RUPREL=
38960+          FILLVOL (1) *FILLFR (1) *DAYMO
38965 ELSEIF ((L.NE.1) .AND. (.NOT. ((IGTANK.AND. (FRACTUG.LT..5))
38970+    .OR.AGTANK))) THEN
38975     IF (RUPREL.GT. (FILLVOL (1) *FILLFR (1) *DAYMO)) RUPREL=
38980+          FILLVOL (1) *FILLFR (1) *DAYMO
38985 ELSE
38990   IF (RUPREL.GT. (TNKCAP (L-1+1/L-L/5) *OPLEV)) THEN
38995              RUPREL=TNKCAP (L-1+1/L-L/5) *OPLEV
39000          ENDIF
39005 ENDIF
39010          DO 1019 II=FALNUM,1,-1
39015             IF (FALNUM1 (II) .EQ.ITYPFLG) THEN
39020               FALNUM2 (II) =FALNUM2 (II) +RUPREL
```

```
              FALNUM5(II)=FALNUM5(II)+DETTIME/60.
              GO TO 1020
            ENDIF
            1019 CONTINUE
            1020 CONTINUE
            FALNUM3(II)=((YR-1)*12)+K
           IF (AGTANK) THEN
           IF (PIPCONT(L).EQ.K)  THEN
                  TEMP=TSURF+SURF+PAGFRAC*RUPREL
             CALL CLENUP(TEMP)
      TSURF=0
      SURF=0
    TPRSURF=0
    PRSURF=0
             RUPREL=(1-PAGFRAC)*RUPREL
         AGRUPT=RUPREL+AGRUPT
          ELSE
      RUPREL=RUPREL+TSURF+SURF
            CALL CLENUP(RUPREL)
      TSURF=0
      SURF=0
    TPRSURF=0
    PRSURF=0
                RUPREL=0.
          ENDIF
       ELSEIF(IGTANK)THEN
            IF (PIPCONT(L).EQ.K)THEN
             TEMP=TSURF+SURF+PAGFRAC*RUPREL
             CALL CLENUP(TEMP)
             TSURF=0
             SURF=0
             TPRSURF=0
             PRSURF=0
            RUPREL=(1-PAGFRAC)*RUPREL
             UGRUPT=RUPREL+UGRUPT
            ELSE
             RUPREL=RUPREL+TSURF+SURF
             CALL CLENUP(RUPREL)
             TSURF=0
             SURF=0
             TPRSURF=0
             PRSURF=0
             DEFREL=0
            ENDIF
        ELSE
IF((UGCONT(L-1+1/L-L/5).EQ.K).OR.NOSECON)THEN
                  TEMP=TSURF+SURF+UGCONFR*RUPREL
           CALL CLENUP(TEMP)
     TSURF=0
     SURF=0
           RUPREL=(1-UGCONFR)*RUPREL
        UGRUPT=RUPREL+UGRUPT
         ELSE
        RUPREL=RUPREL+TSURF+SURF
          CALL CLENUP(RUPREL)
     TSURF=0
     SURF=0
```

```
                  RUPREL=0.
            ENDIF
            ENDIF
            WLVOL(L)=WLVOL(L)+RUPREL
              MONREL=RUPREL+MONREL
               DETECT=.FALSE.
           IF  (((MAX(DETTIME,TREMDT))-TREMDT).NE.0)  THEN
              TREMDT=DETTIME
              TREMRT=RPWLRT(L)
           ENDIF
         CALL FIX(DLAB,K,YR,L,10)
      CALL VAPZERO(4,L)
        IF(WLDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,7)
             12        CONTINUE
  ENDIF
            RUPREL=0
             55     CONTINUE
     DO 56 L=1,NPI
*    PIPE CORROSION LEAK
         IF(PIPLK(L).EQ.K)THEN
       ITYPFLG=3010+L
            IF(PILKVOL(L).EQ.0)THEN
           FALNUM=FALNUM+1
           FALNUM1(FALNUM)=ITYPFLG
           FALNUM7(FALNUM)=(YR-1)*12+K
**               NOT A CONTINUOUS LEAK
            IF(AGPIPE)THEN
                  ONGO=.FALSE.
            ELSE
               ONGO=.TRUE.
            ENDIF
            IF(AGPIPE.OR.(UGPIPE.AND.PIPEE(L).GT.0.))THEN
               CALL LEAKRT(ONGO,1,L,1,LKRATE,PILKDIA(L),WD,LN)
            ELSE
            CALL LEAKRT(ONGO,1,L,0,LKRATE,DM,PILKWID(L),PILKLEN(L))
            ENDIF
               ELSE
                 ONGO=.TRUE.
               IF(AGPIPE.OR.(UGPIPE.AND.(PIPEE(L).GT.0.)))THEN
                 PILKDIA(L)=PILKDIA(L)+2*(PCORE(L)+PIEXT(L)
+             +PIEXT2(L)+PIEXLO2(L)+PIEXLOC(L))/12.
                 CALL LEAKRT(ONGO,1,L,1,LKRATE,PILKDIA(L),WD,LN)
               ELSE
         CALL LEAKRT(ONGO,1,L,0,LKRATE,DM,PILKWID(L),PILKLEN(L))
               ENDIF
              ENDIF
                PILKRT(L)=LKRATE
  DETECT=.FALSE.
  IF(MONMETH(7).AND.PIPSEC)THEN
     DLAB='IS'
* INTERSTITIAL MONITORING
     PIINTER(L,2)=FNB(PIINTER(L,1))
     IF(PIINTER(L,2).EQ.0)THEN
        DETTIME=FNU(60.,720.)
        DETECT=.TRUE.
        GO TO 201
     ENDIF
```

```
ENDIF
        DETECT=.FALSE.
        IF (AGPIPE) THEN
            TMIN=.25
            IF (BATCH) T2=CONTVOL (L) /FLOWRT (L)
      IF (CONT) THEN
         T2=(24-OPHRSDY) *60.
         IF (T2.LT. (4.*60.)) T2=4.*60.
       ENDIF
            T1=.25*T2
          CALL RATEDET (PILKRT (L) ,TMIN,T1,T2,DETECT,DETTIME)
   IF (DETTIME.GT. (30.5*24.*60.)) DETECT=.FALSE.
          DLAB='RD'
           IF (DETECT)  GO TO 201
           IF (INVCNTL) THEN
           CALL IMMINV(1,L,PILKRT (L) ,DETECT,DETTIME)
           DLAB='II'
           IF (DETECT)  GO TO 201
           ENDIF
           IF (MONMETH (5)) THEN
             DLAB='VW'
              IF ((PIPCONT (L) .EQ.K) .OR. (.NOT.PIPSEC)) THEN
               IF (.NOT.VAPFLG) THEN
               IF (PILKVAP (L) .EQ.O.) THEN
                    CALL  VAPOR ((4-L) /L,PILKVAP (L) ,DETECT)
                  IF (.NOT.DETECT)  VAPFLG=.TRUE.
             PILKSPH (L) =.0313*POR*VAPWDIS ((4-L) /L) **3
                 ENDIF
                 IF (.NOT.VAPFLG)  THEN
                   SPHTIME=PILKSPH (L) /PILKRT (L)
   IF ((VTIME ((4-L) /L) *PILKRT (L)) .GT.PILKSPH (L) .AND.MAX (SPHTIME,
      PILKVAP (L)) .EQ.PILKVAP (L))  THEN
                    IF (PILKVAP (L) .GT.43200.)  THEN
                        PILKVAP (L) =PILKVAP (L) -43200.
                        DETECT=.FALSE.
                       ELSE
                        DETECT=.TRUE.
                        DETTIME=PILKVAP (L) +1440
                        VAPDET=.TRUE.
                     ENDIF
                     PILKSPH (L) =PILKSPH (L) -MINMO*PILKRT (L)
       ELSE
          DETECT=.FALSE.
          IF (SPHTIME.LT.MINMO) THEN
            DETECT=.TRUE.
            DETTIME=SPHTIME+1440
            VAPDET=.TRUE.
          ELSE
            DETECT=.FALSE.
            PILKSPH (L) =PILKSPH (L) -MINMO*PILKRT (L)
            PILKVAP (L) =PILKVAP (L) -43200
          ENDIF
       ENDIF
                   ENDIF
                   ENDIF
             IF (DETECT) GO TO 201
             ENDIF
```

```
              ENDIF
          ENDIF
          IF(UGPIPE)THEN
             IF(INVCNTL)THEN
             CALL IMMINV(1,L,PILKRT(L),DETECT,DETTIME)
             DLAB='II'
             IF(DETECT) GO TO 201
             ENDIF
             IF(MONMETH(5))THEN
               DLAB='VW'
                IF((PIPCONT(L).EQ.K).OR.(.NOT.PIPSEC))THEN
                 IF(.NOT.VAPFLG)THEN
                 IF(PILKVAP(L).EQ.0.)THEN
                      CALL VAPOR((4-L)/L,PILKVAP(L),DETECT)
                    IF(.NOT.DETECT) VAPFLG=.TRUE.
              PILKSPH(L)=.0313*POR*VAPWDIS((4-L)/L)**3
                  ENDIF
                  IF(.NOT.VAPFLG) THEN
                    SPHTIME=PILKSPH(L)/PILKRT(L)
     IF((VTIME((4-L)/L)*PILKRT(L)).GT.PILKSPH(L).AND.MAX(SPHTIME,
        PILKVAP(L)).EQ.PILKVAP(L)) THEN
                     IF(PILKVAP(L).GT.43200.) THEN
                         PILKVAP(L)=PILKVAP(L)-43200.
                         DETECT=.FALSE.
                        ELSE
                         DETECT=.TRUE.
                         DETTIME=PILKVAP(L)+1440
                         VAPDET=.TRUE.
                       ENDIF
                       PILKSPH(L)=PILKSPH(L)-MINMO*PILKRT(L)
         ELSE
            DETECT=.FALSE.
            IF(SPHTIME.LT.MINMO)THEN
              DETECT=.TRUE.
              DETTIME=SPHTIME+1440
              VAPDET=.TRUE.
            ELSE
              DETECT=.FALSE.
              PILKSPH(L)=PILKSPH(L)-MINMO*PILKRT(L)
              PILKVAP(L)=PILKVAP(L)-43200
            ENDIF
         ENDIF
                     ENDIF
                     ENDIF
                  IF(DETECT)GO TO 201
               ENDIF
            ENDIF
        ENDIF
        IF(PILKVOL(L).EQ.0)THEN
          MOFRAC=FNU(0.,1.)
             IF(L.EQ.1)THEN
PILKVOL(L)=PILKRT(L)*DAYMO*FILLFR(L)*MOFRAC*FILLTIM(L)
     IF(((MAX((PILKVOL(L)/PILKRT(L)),PREMDT))-PREMDT).NE.0) THEN
              PREMDT=PILKVOL(L)/PILKRT(L)
              PREMRT=PILKRT(L)
            ENDIF
            ELSE
        PILKVOL(L)=PILKRT(L)*DAYMO*MOFRAC*DISCFR(L)*DISCTIM(L)
     IF(((MAX((PILKVOL(L)/PILKRT(L)),PREMDT))-PREMDT).NE.0)  THEN
              PREMDT=PILKVOL(L)/PILKRT(L)
              PREMRT=PILKRT(L)
            ENDIF
            ENDIF
             ELSE
            IF(L.EQ.1)THEN
       PILKVOL(L)=PILKRT(L)*DAYMO*FILLFR(L)*FILLTIM(L)
     IF(((MAX((PILKVOL(L)/PILKRT(L)),PREMDT))-PREMDT).NE.0)  THEN
              PREMDT=PILKVOL(L)/PILKRT(L)
              PREMRT=PILKRT(L)
            ENDIF
            ELSE
            PILKVOL(L)=PILKRT(L)*DAYMO*DISCFR(L)*DISCTIM(L)
     IF(((MAX((PILKVOL(L)/PILKRT(L)),PREMDT))-PREMDT).NE.0)  THEN
              PREMDT=PILKVOL(L)/PILKRT(L)
              PREMRT=PILKRT(L)
            ENDIF
            ENDIF
        ENDIF
       IF(AGPIPE)THEN
        IF(PIPCONT(L).EQ.K)THEN
           TSURF=PAGFRAC*PILKVOL(L)+TSURF
           TSUB=(1-PAGFRAC)*PILKVOL(L)+TSUB
      PIVOL(L)=PIVOL(L)+PILKVOL(L)*(1-PAGFRAC)
          ELSE
           TSURF=PILKVOL(L)+TSURF
        ENDIF
       ELSE
          TSUB=PILKVOL(L)+TSUB
      PIVOL(L)=PIVOL(L)+PILKVOL(L)
       ENDIF
       DO 911 II=FALNUM,1,-1
         IF(FALNUM1(II).EQ.ITYPFLG)  THEN
           IF(FALNUM7(II).EQ.((YR-1)*12+K))THEN
            FALNUM2(II)=PILKVOL(L)
            FALNUM5(II)=MOFRAC*720
           ELSE
            FALNUM2(II)=FALNUM2(II)+PILKVOL(L)
            FALNUM5(II)=FALNUM5(II)+720
           ENDIF
           GO TO 912
         ENDIF
         911 CONTINUE
         912 CONTINUE
          FALNUM3(II)=((YR-1)*12)+K
        GO TO 202
  201     LKREL=PILKRT(L)*DETTIME
IF((L.EQ.1).AND.(.NOT.((AGTANK.AND.VERT.AND.(TNKCAP(1)
+  .GT.1000))).OR.(IGTANK.AND.(FRACTUG.LT..5))))THEN
   IF(LKREL.GT.(FILLVOL(1)*FILLFR(1)*DAYMO))LKREL=
+       FILLVOL(1)*FILLFR(1)*DAYMO
ELSEIF((L.NE.1).AND.(.NOT.((IGTANK.AND.(FRACTUG.LT..5))
+  .OR.AGTANK)))THEN
   IF(LKREL.GT.(FILLVOL(1)*FILLFR(1)*DAYMO))LKREL=
+       FILLVOL(1)*FILLFR(1)*DAYMO
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ELSE
  IF(LKREL.GT.(TNKCAP(L-1+1/L-L/5)*OPLEV))THEN
            LKREL=TNKCAP(L-1+1/L-L/5)*OPLEV
        ENDIF
ENDIF
        DO 913 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.ITYPFLG)THEN
            FALNUM2(II)=FALNUM2(II)+LKREL
            FALNUM5(II)=FALNUM5(II)+DETTIME/60.
            GO TO 914
          ENDIF
          913 CONTINUE
          914 CONTINUE
          FALNUM3(II)=((YR-1)*12)+K
        IF(AGPIPE)THEN
         IF(PIPCONT(L).EQ.K)  THEN
                      TEMP=TSURF+SURF+PAGFRAC*LKREL
           CALL CLENUP(TEMP)
     TSURF=0
     SURF=0
           LKREL=(1-PAGFRAC)*LKREL
        AGLEAK=LKREL+AGLEAK
         ELSE
      LKREL=LKREL+TSURF+SURF
          CALL CLENUP(LKREL)
     TSURF=0
     SURF=0
                LKREL=0.
         ENDIF
          ELSE
           UGLEAK=LKREL+UGLEAK
        ENDIF
         PIVOL(L)=PIVOL(L)+LKREL
        MONREL=LKREL+MONREL
        DETECT=.FALSE.
        IF  (((MAX(DETTIME,PREMDT))-PREMDT).NE.0)  THEN
           PREMDT=DETTIME
           PREMRT=PILKRT(L)
        ENDIF
      CALL FIX(DLAB,K,YR,L,4)
      CALL FIX(DLAB,K,YR,L,9)
   CALL VAPZERO(1,L)
     IF(PIDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,6)
     IF(GKDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,8)
     IF(WLDEFVL(L).GT.0)  CALL FIX(DLAB,K,YR,L,7)
        IF(RPPIVOL(L).GT.0)  CALL FIX(DLAB,K,YR,L,5)
        IF(RPWLVOL(L).GT.0)  CALL FIX(DLAB,K,YR,L,10)
     202 CONTINUE
      ENDIF
      LKREL=0
      56 CONTINUE
   DO 57 L=1,NPI
*  PUMP CORROSION LEAK
     IF(PMPLK(L).EQ.K)THEN
     ITYPFLG=3020+L
         IF(PMLKVOL(L).EQ.0)THEN
        FALNUM=FALNUM+1
```

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40735           FALNUM1(FALNUM)=ITYPFLG
40740           FALNUM7(FALNUM)=(YR-1)*12+K
40745*              NOT A CONTINUOUS LEAK
40750               ONGO=.FALSE.
40755               CALL LEAKRT(ONGO,2,L,1,LKRATE,PMLKDIA(L),WD,LN)
40760                      ELSE
40765*               APPLY A GROWTH FACTOR
40770               PMLKDIA(L)=PMLKDIA(L)+2*(PMCORE(L)+PMEXT(L))/12.
40775               ONGO=.TRUE.
40780               CALL LEAKRT(ONGO,2,L,1,LKRATE,PMLKDIA(L),WD,LN)
40785             ENDIF
40790                 PMLKRT(L)=LKRATE
40795             DETECT=.FALSE.
40800              IF(AGPUMP)THEN
40805             TMIN=.25
40810        IF(BATCH)T2=CONTVOL(L)/FLOWRT(L)
40815         IF(CONT)THEN
40820           T2=(24-OPHRSDY)*60.
40825           IF(T2.LT.(4.*60.))T2=4.*60.
40830          ENDIF
40835             T1=.25*T2
40840               CALL RATEDET(PMLKRT(L),TMIN,T1,T2,DETECT,DETTIME)
40845   IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
40850            DLAB='RD'
40855                IF(DETECT) GO TO 211
40860                IF(INVCNTL)THEN
40865                CALL IMMINV(2,L,PMLKRT(L),DETECT,DETTIME)
40870             DLAB='II'
40875                IF(DETECT) GO TO 211
40880                ENDIF
40885                IF(MONMETH(5))THEN
40890               DLAB='VW'
40895 IF((PIPCONT(L).EQ.K).OR.NOSECON)THEN
40900                 IF(.NOT.VAPFLG)THEN
40905                 IF(PMPVAP(L).EQ.0.)THEN
40910                      CALL VAPOR(2,PMPVAP(L),DETECT)
40915                    IF(.NOT.DETECT) VAPFLG=.TRUE.
40920               PMPSPH(L)=.0313*POR*VAPWDIS(2)**3
40925                   ENDIF
40930                   IF(.NOT.VAPFLG) THEN
40935                     SPHTIME=PMPSPH(L)/PMLKRT(L)
40940    IF((VTIME(2)*PMLKRT(L)).GT.PMPSPH(L).AND.MAX(SPHTIME,
40945+      PMPVAP(L)).EQ.PMPVAP(L)) THEN
40950                      IF(PMPVAP(L).GT.43200.) THEN
40955                          PMPVAP(L)=PMPVAP(L)-43200.
40960                          DETECT=.FALSE.
40965                         ELSE
40970                          DETECT=.TRUE.
40975                          DETTIME=PMPVAP(L)+1440
40980                          VAPDET=.TRUE.
40985                        ENDIF
40990                        PMPSPH(L)=PMPSPH(L)-MINMO*PMLKRT(L)
40995        ELSE
41000           DETECT=.FALSE.
41005           IF(SPHTIME.LT.MINMO)THEN
41010             DETECT=.TRUE.
41015             DETTIME=SPHTIME+1440
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        VAPDET=.TRUE.
      ELSE
        DETECT=.FALSE.
        PMPSPH (L) =PMPSPH (L) -MINMO*PMLKRT (L)
        PMPVAP (L) =PMPVAP (L) -43200
      ENDIF
   ENDIF
               ENDIF
               ENDIF
               IF (DETECT) GO TO 211
            ENDIF
         ENDIF
      ENDIF
        IF (PMLKVOL (L) .EQ.O) THEN
     MOFRAC=FNU (O.,1.)
 IF (L.EQ.1) THEN
  PMLKVOL (L) =PMLKRT (L) *DAYMO*FILLFR (L) *MOFRAC*FILLTIM (L)
 ELSE
    PMLKVOL (L) =PMLKRT (L) *DAYMO*DISCFR (L) *DISCTIM (L) *MOFRAC
 ENDIF
IF (((MAX ((PMLKVOL (L) /PMLKRT (L)) ,PREMDT)) -PREMDT) .NE.O)  THEN
         PREMDT=PMLKVOL (L) /PMLKRT (L)
         PREMRT=PMLKRT (L)
       ENDIF
        ELSE
 IF (L.EQ.1) THEN
         PMLKVOL (L) =PMLKRT (L) *DAYMO*FILLFR (L) *FILLTIM (L)
 ELSE
    PMLKVOL (L) =PMLKRT (L) *DAYMO*DISCFR (L) *DISCTIM (L)
 ENDIF
IF (((MAX ((PMLKVOL (L) /PMLKRT (L)) ,PREMDT)) -PREMDT) .NE.O)  THEN
         PREMDT=PMLKVOL (L) /PMLKRT (L)
         PREMRT=PMLKRT (L)
       ENDIF
        ENDIF
 IF (PIPCONT (L) .EQ.K) THEN
        TSURF=PAGFRAC*PMLKVOL (L) +TSURF
         TSUB= (1-PAGFRAC) *PMLKVOL (L) +TSUB
    PMVOL (L) =PMVOL (L) +PMLKVOL (L) * (1-PAGFRAC)
            ELSE
         TSURF=PMLKVOL (L) +TSURF
     ENDIF
  DO 1021 II=FALNUM,1,-1
    IF (FALNUM1 (II) .EQ.ITYPFLG)  THEN
      IF (FALNUM7 (II) .EQ. ((YR-1) *12+K)) THEN
       FALNUM2 (II) =PMLKVOL (L)
       FALNUM5 (II) =MOFRAC*720
      ELSE
       FALNUM2 (II) =FALNUM2 (II) +PMLKVOL (L)
       FALNUM5 (II) =FALNUM5 (II) +720
      ENDIF
      GO TO 1022
    ENDIF
    1021 CONTINUE
    1022 CONTINUE
     FALNUM3 (II) = ((YR-1) *12) +K
       GO TO 212
     211 -  CONTINUE
        LKREL=PMLKRT(L)*DETTIME
   IF(LKREL.GT.(FILLVOL(1)*FILLFR(1)*DAYMO))LKREL=
  FILLVOL(1)*FILLFR(1)*DAYMO
    DO 1023 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.ITYPFLG)THEN
         FALNUM2(II)=FALNUM2(II)+LKREL
         FALNUM5(II)=FALNUM5(II)+DETTIME/60.
         GO TO 1024
       ENDIF
       1023 CONTINUE
       1024 CONTINUE
       FALNUM3(II)=((YR-1)*12)+K
       FALNUM6(II)=DLAB
  IF  (PIPCONT(L).EQ.K)  THEN
         TEMP=TSURF+SURF+PAGFRAC*LKREL
           CALL  CLENUP(TEMP)
  TSURF=0
  SURF=0
           AGLEAK=(1-PAGFRAC)*LKREL+AGLEAK
        ELSE
   LKREL=LKREL+TSURF+SURF
           CALL  CLENUP(LKREL)
  TSURF=0
  SURF=0
                 LKREL=0.
        ENDIF
       PMVOL(L)=PMVOL(L)+LKREL
        MONREL=LKREL+MONREL
         DETECT=.FALSE.
     IF  (((MAX(DETTIME,PREMDT))-PREMDT).GT.0)  THEN
        PREMDT=DETTIME
        PREMRT=PMLKRT(L)
     ENDIF
         PMLKVOL(L)=0
      PMPVAP(L)=0.
         PMLKRT(L)=0
         PMPLK(L)=0
       CALL  REPLAC(2,L)
   CALL  INTREPL(2,L)
        DO  1069  IJ=FALNUM,1,-1
          IF(MOD(FALNUM1(IJ),100).EQ.(20+L))GO TO 1135
        1069 CONTINUE
1135 PREMREP=.TRUE.
 PMREPAR(L)=.TRUE.
      DLPMP(L)=.TRUE.
      PUMPI(L)=IPUMP(L)
      PUMPE(L)=IPUMP(L)
   212    CONTINUE
    ENDIF
    LKREL=0
 57 CONTINUE
DO 58 L=1,NPI
  GASKETED FLANGE LEAK
   IF(GSKLK(L).EQ.K)THEN
  ITYPFLG=3050+L
       IF(GKLKVOL(L).EQ.0)  THEN
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41590         FALNUM=FALNUM+1
41595         FALNUM1(FALNUM)=ITYPFLG
41600         FALNUM7(FALNUM)=(YR-1)*12+K
41605                   ONGO=.FALSE.
41610             CALL LEAKRT(ONGO,5,L,1,LKRATE,GKLKDIA(L),WD,LN)
41615                    ELSE
41620***       APPLY GROWTH FACTOR
41625          ENDIF
41630         IF(GKLKVOL(L).EQ.0)THEN
41635**    NOT A CONTINUOUS LEAK
41640            GKLKRT(L)=LKRATE
41645         ENDIF
41650         DETECT=.FALSE.
41655         IF(AGTANK)THEN
41660            TMIN=30.
41665       IF(L.EQ.1)THEN
41670           T2=CONTVOL(L)/FLOWRT(L)
41675       IF(CONT)THEN
41680          T2=(24-OPHRSDY)*60.
41685          IF(T2.LT.(4.*60.))T2=4.*60.
41690        ENDIF
41695       ELSE
41700           T2=MINMO
41705          IF(WEEKINS)T2=10080.
41710       IF(CONT)THEN
41715          T2=(24-OPHRSDY)*60.
41720          IF(T2.LT.(4.*60.))T2=4.*60.
41725        ENDIF
41730       ENDIF
41735             T1=T2
41740           CALL RATEDET(GKLKRT(L),TMIN,T1,T2,DETECT,DETTIME)
41745     IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
41750           DLAB= RD'
41755 IF((CONT.AND.STORAGE).AND.(DETTIME.GT.(OPLEV*TNKCAP(INT(
41760+L-1+1/L-L/5))/GKLKRT(L)
41765+)))DETTIME=OPLEV*TNKCAP(L-1+1/L-L/5)/GKLKRT(L)
41770 IF(DETTIME.GT.(TNKCAP(L-1+1/L-L/5)/GKLKRT(L)))
41775+   DETTIME=TNKCAP(L-1+1/L-L/5)/GKLKRT(L)
41780             IF(DETECT)  GO TO 207
41785             IF(INVCNTL)THEN
41790             CALL  IMMINV(5,L,GKLKRT(L),DETECT,DETTIME)
41795             DLAB='II'
41800             IF(DETECT)  GO TO 207
41805             ENDIF
41810             IF(MONMETH(5))THEN
41815               DLAB='VW'
41820     IF((AGCONT(L-1+1/L-L/5).EQ.K).OR.NOSECON)THEN
41825                 IF(.NOT.VAPFLG)THEN
41830                 IF(WGLRVAP(L).EQ.0.)THEN
41835                      CALL VAPOR(3,WGLRVAP(L),DETECT)
41840                    IF(.NOT.DETECT) VAPFLG=.TRUE.
41845               GKLKSPH(L)=.0313*POR*VAPWDIS(3)**3
41850                   ENDIF
41855                   IF(.NOT.VAPFLG) THEN
41860                     SPHTIME=GKLKSPH(L)/GKLKRT(L)
41865      IF((VTIME(3)*GKLKRT(L)).GT.GKLKSPH(L).AND.MAX(SPHTIME,
41870+        WGLRVAP(L)).EQ.WGLRVAP(L)) THEN
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41875                    IF(WGLRVAP(L).GT.43200.)  THEN
41880                      WGLRVAP(L)=WGLRVAP(L)-43200.
41885                      DETECT=.FALSE.
41890                     ELSE
41895                      DETECT=.TRUE.
41900                      DETTIME=WGLRVAP(L)+1440
41905                      VAPDET=.TRUE.
41910                    ENDIF
41915                    GKLKSPH(L)=GKLKSPH(L)-MINMO*GKLKRT(L)
41920           ELSE
41925             DETECT=.FALSE.
41930             IF(SPHTIME.LT.MINMO)THEN
41935               DETECT=.TRUE.
41940               DETTIME=SPHTIME+1440
41945               VAPDET=.TRUE.
41950             ELSE
41955               DETECT=.FALSE.
41960               GKLKSPH(L)=GKLKSPH(L)-MINMO*GKLKRT(L)
41965               WGLRVAP(L)=WGLRVAP(L)-43200
41970             ENDIF
41975           ENDIF
41980                   ENDIF
41985                   ENDIF
41990                 IF(DETECT)GO TO 207
41995               ENDIF
42000             ENDIF
42005            ELSE
42010*             UGTANK.OR.IGTANK
42015        IF(MONMETH(2).AND.VAULT)THEN
42020        DLAB='IS'
42025******     INTERSTITIAL MONITORING
42030   INTERST(L-1+1/L-L/5,2)=FNB(INTERST(
42035+L-1+1/L-L/5,1))
42040           IF(INTERST(L-1+1/L-L/5,2).EQ.0)THEN
42045              IF(VAULT)THEN
42050                  DETTIME=FNU(5./GKLKRT(L),MINMO)
42055               ELSE
42060                DETTIME=FNU(60.,720.)
42065              ENDIF
42070             DETECT=.TRUE.
42075              GO TO 207
42080           ENDIF
42085        ENDIF
42090         IF(IGTANK)THEN
42095              TMIN=30.
42100              T2=MINMO
42105            IF(WEEKINS)T2=10080.
42110         IF(CONT)THEN
42115            T2=(24-OPHRSDY)*60.
42120            IF(T2.LT.(4.*60.))T2=4.*60.
42125          ENDIF
42130              T1=T2
42135          CALL RATEDET(GKLKRT(L),TMIN,T1,T2,DETECT,DETTIME)
42140      IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
42145            DLAB='RD'
42150 IF((CONT.AND.STORAGE).AND.(DETTIME.GT.(OPLEV*TNKCAP(INT(
42155+L-1+1/L-L/5))/GKLKRT(L)
42160+)))DETTIME=OPLEV*TNKCAP(L-1+1/L-L/5)/GKLKRT(L)
42165 IF(DETTIME.GT.(TNKCAP(L-1+1/L-L/5)/GKLKRT(L)))
42170+  DETTIME=TNKCAP(L-1+1/L-L/5)/GKLKRT(L)
42175          IF(DETECT) GO TO 207
42180       ENDIF
42185            IF(INVCNTL)THEN
42190            CALL IMMINV(5,L,GKLKRT(L),DETECT,DETTIME)
42195            DLAB='II'
42200            IF(DETECT) GO TO 207
42205            ENDIF
42210            IF(MONMETH(5))THEN
42215              DLAB='VW'
42220               IF((UGCONT(L).EQ.K).OR.NOSECON)THEN
42225                IF(.NOT.VAPFLG)THEN
42230                IF(WGLRVAP(L).EQ.0.)THEN
42235                     CALL VAPOR(3,WGLRVAP(L),DETECT)
42240                   IF(.NOT.DETECT) VAPFLG=.TRUE.
42245              GKLKSPH(L)=.0313*POR*VAPWDIS(3)**3
42250                  ENDIF
42255                  IF(.NOT.VAPFLG) THEN
42260                    SPHTIME=GKLKSPH(L)/GKLKRT(L)
42265     IF((VTIME(3)*GKLKRT(L)).GT.GKLKSPH(L).AND.MAX(SPHTIME,
42270+       WGLRVAP(L)).EQ.WGLRVAP(L)) THEN
42275                     IF(WGLRVAP(L).GT.43200.) THEN
42280                         WGLRVAP(L)=WGLRVAP(L)-43200.
42285                         DETECT=.FALSE.
42290                        ELSE
42295                         DETECT=.TRUE.
42300                         DETTIME=WGLRVAP(L)+1440
42305                         VAPDET=.TRUE.
42310                       ENDIF
42315                       GKLKSPH(L)=GKLKSPH(L)-MINMO*GKLKRT(L)
42320         ELSE
42325            DETECT=.FALSE.
42330            IF(SPHTIME.LT.MINMO)THEN
42335              DETECT=.TRUE.
42340              DETTIME=SPHTIME+1440
42345              VAPDET=.TRUE.
42350            ELSE
42355              DETECT=.FALSE.
42360              GKLKSPH(L)=GKLKSPH(L)-MINMO*GKLKRT(L)
42365              WGLRVAP(L)=WGLRVAP(L)-43200
42370            ENDIF
42375         ENDIF
42380                     ENDIF
42385                     ENDIF
42390                  IF(DETECT) GO TO 207
42395               ENDIF
42400             ENDIF
42405         ENDIF
42410              IF(GKLKVOL(L).EQ.0)THEN
42415           MOFRAC=FNU(0.,1.)
42420  IF(((L.EQ.1).AND.(FRACTUG.GE..5)).OR.((L.EQ.1).AND.AGTANK.AND.
42425+ (HORIZ.OR.(VERT.AND.(TNKCAP(L-1+1/L-L/5)
42430+.LE.1000)))))THEN
42435   GKLKVOL(L)=GKLKRT(L)*DAYMO*FILLFR(L)*MOFRAC*FILLTIM(L)
42440      IF(((MAX((GKLKVOL(L)/GKLKRT(L)),TREMDT))-TREMDT).NE.0) THEN
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42445                TREMDT=GKLKVOL(L)/GKLKRT(L)
42450                TREMRT=GKLKRT(L)
42455              ENDIF
42460              ELSE
42465  GKLKVOL(L)=GKLKRT(L)*MINMO*MOFRAC*TANKTIM(
42470+L-1+1/L-L/5)
42475      IF(((MAX((GKLKVOL(L)/GKLKRT(L)),TREMDT))-TREMDT).NE.0)  THEN
42480                TREMDT=GKLKVOL(L)/GKLKRT(L)
42485                TREMRT=GKLKRT(L)
42490              ENDIF
42495              ENDIF
42500        IF(GKLKVOL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))
42505+       GKLKVOL(L)=FILLVOL(1)*FILLFR(1)*30.
42510               ELSE
42515 IF(((L.EQ.1).AND.(FRACTUG.GE..5)).OR.((L.EQ.1).AND.AGTANK.AND.
42520+ (HORIZ.OR.(VERT.AND.(TNKCAP(L-1+1/L-L/5)
42525+.LE.1000)))))THEN
42530          GKLKVOL(L)=GKLKRT(L)*DAYMO*FILLFR(L)*FILLTIM(L)
42535      IF(((MAX((GKLKVOL(L)/GKLKRT(L)),TREMDT))-TREMDT).NE.0)  THEN
42540                TREMDT=GKLKVOL(L)/GKLKRT(L)
42545                TREMRT=GKLKRT(L)
42550              ENDIF
42555              ELSE
42560 GKLKVOL(L)=GKLKRT(L)*MINMO*TANKTIM(L-1+1/L-L/5)
42565      IF(((MAX((GKLKVOL(L)/GKLKRT(L)),TREMDT))-TREMDT).NE.0)  THEN
42570                TREMDT=GKLKVOL(L)/GKLKRT(L)
42575                TREMRT=GKLKRT(L)
42580              ENDIF
42585              ENDIF
42590        IF(GKLKVOL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))
42595+       GKLKVOL(L)=FILLVOL(1)*FILLFR(1)*30.
42600               ENDIF
42605         IF(AGTANK)THEN
42610     IF(PIPCONT(L).EQ.K)THEN
42615               TSURF=PAGFRAC*GKLKVOL(L)+TSURF
42620               TSUB=(1-PAGFRAC)*GKLKVOL(L)+TSUB
42625          GKVOL(L)=GKVOL(L)+GKLKVOL(L)*(1-PAGFRAC)
42630              ELSE
42635               TSURF=GKLKVOL(L)+TSURF
42640            ENDIF
42645       ELSEIF(IGTANK)THEN
42650          IF(PIPCONT(L).EQ.K)THEN
42655             TSURF=PAGFRAC*GKLKVOL(L)+TSURF
42660             TSUB=(1-PAGFRAC)*GKLKVOL(L)+TSUB
42665             GKVOL(L)=GKVOL(L)+GKLKVOL(L)*(1-PAGFRAC)
42670           ELSE
42675             TSURF=GKLKVOL(L)+TSURF
42680           ENDIF
42685           ELSE
42690*              UGTANK
42695              IF(VAULT)THEN
42700    IF(UGCONT(L-1+1/L-L/5).EQ.K)THEN
42705                TSURF=UGCONFR*GKLKVOL(L)+TSURF
42710                TSUB=(1-UGCONFR)*GKLKVOL(L)+TSUB
42715          GKVOL(L)=GKVOL(L)+GKLKVOL(L)*(1-UGCONFR)
42720               ELSE
42725                TSURF=GKLKVOL(L)+TSURF
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            ENDIF
            ELSE
              TSUB=GKLKVOL (L)+TSUB
          GKVOL (L)=GKVOL (L)+GKLKVOL (L)
            ENDIF
     38941 CONTINUE
           ENDIF
        DO 1025 II=FALNUM,1,-1
          IF (FALNUM1 (II) .EQ.ITYPFLG)  THEN
            IF (FALNUM7 (II) .EQ. ((YR-1) *12+K)) THEN
             FALNUM2 (II)=GKLKVOL (L)
             FALNUM5 (II)=MOFRAC*720
            ELSE
             FALNUM2 (II)=FALNUM2 (II)+GKLKVOL (L)
             FALNUM5 (II)=FALNUM5 (II)+720
            ENDIF
            GO TO 1026
          ENDIF
          1025 CONTINUE
          1026 CONTINUE
           FALNUM3 (II)=((YR-1) *12)+K
           GO TO 208
 207       LKREL=GKLKRT (L) *DETTIME
IF ((L.EQ.1) .AND. (.NOT. ((AGTANK.AND.VERT.AND. (TNKCAP (1)
   .GT.1000))) .OR. (IGTANK.AND. (FRACTUG.LT..5)))) THEN
   IF (LKREL.GT. (FILLVOL (1) *FILLFR (1) *DAYMO)) LKREL=
        FILLVOL (1) *FILLFR (1) *DAYMO
ELSEIF ((L.NE.1) .AND. (.NOT. ((IGTANK.AND. (FRACTUG.LT..5))
   .OR.AGTANK))) THEN
   IF (LKREL.GT. (FILLVOL (1) *FILLFR (1) *DAYMO)) LKREL=
        FILLVOL (1) *FILLFR (1) *DAYMO
ELSE
 IF (LKREL.GT. (TNKCAP (L-1+1/L-L/5) *OPLEV)) THEN
            LKREL=TNKCAP (L-1+1/L-L/5) *OPLEV
        ENDIF
ENDIF
        DO 1027 II=FALNUM,1,-1
          IF (FALNUM1 (II) .EQ.ITYPFLG) THEN
            FALNUM2 (II)=FALNUM2 (II)+LKREL
            FALNUM5 (II)=FALNUM5 (II)+DETTIME/60.
            GO TO 1028
          ENDIF
          1027 CONTINUE
          1028 CONTINUE
          FALNUM3 (II)=((YR-1) *12)+K
          IF (AGTANK.OR. (IGTANK.AND.RETROFT)) THEN
         IF (PIPCONT (L) .EQ.K)  THEN
                    TEMP=TSURF+SURF+PAGFRAC*LKREL
           CALL CLENUP (TEMP)
     TSURF=0
     SURF=0
           LKREL=(1-PAGFRAC) *LKREL
        AGLEAK=LKREL+AGLEAK
         ELSE
      LKREL=LKREL+TSURF+SURF
          CALL CLENUP (LKREL)
     TSURF=0
     SURF=0
               LKREL=O.
          ENDIF
      ELSEIF(IGTANK)THEN
           IF(PIPCONT(L).EQ.K)THEN
            TEMP=TSURF+SURF+PAGFRAC*LKREL
            CALL CLENUP(TEMP)
            TSURF=0
            SURF=0
            TPRSURF=0
            PRSURF=0
          LKREL=(1-PAGFRAC)*LKREL
           UGLEAK=LKREL+UGLEAK
          ELSE
           LKREL=LKREL+TSURF+SURF
           CALL CLENUP(LKREL)
           TSURF=0
           SURF=0
           TPRSURF=0
           PRSURF=C
           LKREL=0
          ENDIF
       ELSE
IF((UGCONT(L-1+1/L-L/5).EQ.K).OR.NOSECON)THEN
                      TEMP=TSURF+SURF+UGCONFR*LKREL
           CALL CLENUP(TEMP)
     TSURF=0
     SURF=0
           LKREL=(1-UGCONFR)*LKREL
        UGLEAK=LKREL+UGLEAK
         ELSE
      LKREL=LKREL+TSURF+SURF
          CALL CLENUP(LKREL)
     TSURF=0
     SURF=0
               LKREL=0.
         ENDIF
         ENDIF
         GKVOL(L)=GKVOL(L)+LKREL
         MONREL=LKREL+MONREL
         DETECT=.FALSE.
        IF (((MAX(DETTIME,TREMDT))-TREMDT).NE.0)  THEN
           TREMDT=DETTIME
           TREMRT=GKLKRT(L)
        ENDIF
      CALL FIX(DLAB,K,YR,L,9)
   CALL VAPZERO(5,L)
IF(GKDEFVL(L).GT.0)CALL FIX(DLAB,K,YR,L,8)
208    CONTINUE
 ENDIF
     LKREL=0
  58 CONTINUE
  DO 5843 L=1,NTK
*    TANK CORROSION LEAK
  IF(TNKLK(L).EQ.K)THEN
    ITYPFLG=3030+L
     IF(TKLKVOL(L).EQ.0)THEN
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43300         FALNUM=FALNUM+1
43305         FALNUM1(FALNUM)=ITYPFLG
43310         FALNUM7(FALNUM)=(YR-1)*12+K
43315             ONGO=.FALSE.
43320           CALL LEAKRT(ONGO,3,1,1,LKRATE,TKLKDIA(L),WD,LN)
43325           TKLKRT(L)=LKRATE
43330         ELSE
43335*  APPLY GROWTH FACTOR
43340        TKLKDIA(L)=TKLKDIA(L)+2*(TCORE(L)+TKEXT(L)
43345+        +TKEXT2(L)+TKEXLOC(L)+TKEXLO2(L))/12.
43350        ONGO=.TRUE.
43355    CALL LEAKRT(ONGO,3,1,1,LKRATE,TKLKDIA(L),WD,LN)
43360        TKLKRT(L)=LKRATE
43365       ENDIF
43370      DETECT=.FALSE.
43375      IF(MONMETH(2).AND.VAULT)THEN
43380      DLAB='IS'
43385******    INTERSTITIAL MONITORING
43390         INTERST(L,2)=FNB(INTERST(L,1))
43395         IF(INTERST(L,2).EQ.0)THEN
43400             IF(VAULT)THEN
43405                   DETTIME=FNU(5./TKLKRT(L),MINMO)
43410                 ELSE
43415                     DETTIME=FNU(60.,720.)
43420             ENDIF
43425            DETECT=.TRUE.
43430            GO TO 205
43435         ENDIF
43440      ENDIF
43445      IF(AGTANK.AND.CRADLE)THEN
43450             TMIN=30.
43455             T2=MINMO
43460          IF(WEEKINS)T2=10080.
43465       IF(CONT)THEN
43470          T2=(24-OPHRSDY)*60.
43475          IF(T2.LT.(4.*60.))T2=4.*60.
43480        ENDIF
43485             T1=T2
43490        CALL RATEDET(TKLKRT(L),TMIN,T1,T2,DETECT,DETTIME)
43495    IF(DETTIME.GT.(30.5*24.*60.))DETECT=.FALSE.
43500           DLAB='RD'
43505 IF((CONT.AND.STORAGE).AND.(DETTIME.GT.(OPLEV*TNKCAP(L)/TKLKRT(L))
43510+  ))DETTIME=OPLEV*TNKCAP(L)/TKLKRT(L)
43515       IF(DETTIME.GT.(TNKCAP(L)/TKLKRT(L)))DETTIME=TNKCAP(L)/
43520+     TKLKRT(L)
43525         IF(DETECT) GO TO 205
43530         IF(INVCNTL)THEN
43535         CALL IMMINV(3,1,TKLKRT(L),DETECT,DETTIME)
43540            DLAB='II'
43545         IF(DETECT) GO TO 205
43550         ENDIF
43555         IF(MONMETH(5))THEN
43560              DLAB='VW'
43565 IF((AGCONT(L).EQ.K).OR.(AGTANK.AND.(.NOT.CRADLE)).OR.(NOSECON))
43570+THEN
43575                IF(.NOT.VAPFLG)THEN
43580                IF(TKLKVAP.EQ.0.)THEN
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```
                      CALL VAPOR(3,TKLKVAP,DETECT)
                    IF(.NOT.DETECT) VAPFLG=.TRUE.
               TKLKSPH=.0313*POR*VAPWDIS(3)**3
                   ENDIF
                   IF(.NOT.VAPFLG) THEN
                     SPHTIME=TKLKSPH/TKLKRT(L)
      IF((VTIME(3)*TKLKRT(L)).GT.TKLKSPH.AND.MAX(SPHTIME,
         TKLKVAP).EQ.TKLKVAP) THEN
                      IF(TKLKVAP.GT.43200.) THEN
                          TKLKVAP=TKLKVAP-43200.
                          DETECT=.FALSE.
                         ELSE
                          DETECT=.TRUE.
                          DETTIME=TKLKVAP+1440
                          VAPDET=.TRUE.
                        ENDIF
                        TKLKSPH=TKLKSPH-MINMO*TKLKRT(L)
          ELSE
             DETECT=.FALSE.
             IF(SPHTIME.LT.MINMO)THEN
               DETECT=.TRUE.
               DETTIME=SPHTIME+1440
               VAPDET=.TRUE.
             ELSE
               DETECT=.FALSE.
               TKLKSPH=TKLKSPH-MINMO*TKLKRT(L)
               TKLKVAP=TKLKVAP-43200
             ENDIF
          ENDIF
                      ENDIF
                      ENDIF
                IF(DETECT) GO TO 205
             ENDIF
          ENDIF
       ENDIF
       IF(UGTANK.OR.IGTANK)THEN
          IF(INVCNTL)THEN
          CALL IMMINV(3,1,TKLKRT(L),DETECT,DETTIME)
             DLAB='II'
          IF(DETECT) GO TO 205
          ENDIF
          IF(MONMETH(5))THEN
               DLAB='VW'
             IF((UGCONT(L).EQ.K).OR.NOSECON)THEN
                 IF(.NOT.VAPFLG)THEN
                 IF(TKLKVAP.EQ.0.)THEN
                      CALL VAPOR(3,TKLKVAP,DETECT)
                    IF(.NOT.DETECT) VAPFLG=.TRUE.
               TKLKSPH=.0313*POR*VAPWDIS(3)**3
                   ENDIF
                   IF(.NOT.VAPFLG) THEN
                     SPHTIME=TKLKSPH/TKLKRT(L)
      IF((VTIME(3)*TKLKRT(L)).GT.TKLKSPH.AND.MAX(SPHTIME,
         TKLKVAP).EQ.TKLKVAP) THEN
                      IF(TKLKVAP.GT.43200.) THEN
                          TKLKVAP=TKLKVAP-43200.
                          DETECT=.FALSE.
                        ELSE
                         DETECT=.TRUE.
                         DETTIME=TKLKVAP+1440
                         VAPDET=.TRUE.
                       ENDIF
                       TKLKSPH=TKLKSPH-MINMO*TKLKRT(L)
         ELSE
            DETECT=.FALSE.
            IF(SPHTIME.LT.MINMO)THEN
              DETECT=.TRUE.
              DETTIME=SPHTIME+1440
              VAPDET=.TRUE.
            ELSE
              DETECT=.FALSE.
              TKLKSPH=TKLKSPH-MINMO*TKLKRT(L)
              TKLKVAP=TKLKVAP-43200
            ENDIF
         ENDIF
                     ENDIF
                     ENDIF
               IF(DETECT)GO TO 205
            ENDIF
         ENDIF
      ENDIF
      IF(TKLKVOL(L).EQ.0)THEN
           MOFRAC=FNU(0.,1.)
*****    LEAKS FOR A FULL MONTH IF NOT DETECTED IN PRIOR MONTH
         TKLKVOL(L)=TKLKRT(L)*MINMO*MOFRAC*TANKTIM(L)
      IF(((MAX((TKLKVOL(L)/TKLKRT(L)),TREMDT))-TREMDT).NE.0)  THEN
               TREMDT=TKLKVOL(L)/TKLKRT(L)
               TREMRT=TKLKRT(L)
             ENDIF
          IF(TKLKVOL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))THEN
             TKLKVOL(L)=FILLVOL(1)*FILLFR(1)*30.
          ENDIF
        ELSE
         TKLKVOL(L)=TKLKRT(L)*MINMO*TANKTIM(L)
      IF(((MAX((TKLKVOL(L)/TKLKRT(L)),TREMDT))-TREMDT).NE.0)  THEN
               TREMDT=TKLKVOL(L)/TKLKRT(L)
               TREMRT=TKLKRT(L)
             ENDIF
          IF(TKLKVOL(L).GT.(FILLVOL(1)*FILLFR(1)*30.))THEN
             TKLKVOL(L)=FILLVOL(1)*FILLFR(1)*30.
          ENDIF
      ENDIF
      IF(AGTANK)THEN
          IF((AGCONT(L).EQ.K).OR.(AGTANK.AND.(.NOT.CRADLE)))  THEN
            TSURF=AGCONFR*TKLKVOL(L)+TSURF
            TSUB=(1-AGCONFR)*TKLKVOL(L)+TSUB
       TKVOL(L)=TKVOL(L)+TKLKVOL(L)*(1-AGCONFR)
           ELSE
            TSURF=TKLKVOL(L)+TSURF
         ENDIF
        ELSE
*     UGTANK
            IF(VAULT)THEN
         IF(UGCONT(L).EQ.K)THEN
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          TSURF=(UGCONFR)*TKLKVOL(L)+TSURF
          TSUB=(1-UGCONFR)*TKLKVOL(L)+TSUB
     TKVOL(L)=TKVOL(L)+TKLKVOL(L)*(1-UGCONFR)
         ELSE
          TSURF=TKLKVOL(L)+TSURF
       ENDIF
          ELSE
            TSUB=TKLKVOL(L)+TSUB
     TKVOL(L)=TKVOL(L)+TKLKVOL(L)
          ENDIF
    ENDIF
      DO 1029 II=FALNUM,1,-1
        IF(FALNUM1(II).EQ.ITYPFLG) THEN
          IF(FALNUM7(II).EQ.((YR-1)*12+K))THEN
           FALNUM2(II)=TKLKVOL(L)
           FALNUM5(II)=MOFRAC*720
          ELSE
           FALNUM2(II)=FALNUM2(II)+TKLKVOL(L)
           FALNUM5(II)=FALNUM5(II)+720
          ENDIF
          GO TO 1030
        ENDIF
        1029 CONTINUE
        1030 CONTINUE
         FALNUM3(II)=((YR-1)*12)+K
    GO TO 206
205   LKREL=TKLKRT(L)*DETTIME
      IF(LKREL.GT.(TNKCAP(L)*OPLEV))THEN
           LKREL=TNKCAP(L)*OPLEV
       ENDIF
       DO 1031 II=FALNUM,1,-1
         IF(FALNUM1(II).EQ.ITYPFLG)THEN
           FALNUM2(II)=FALNUM2(II)+LKREL
           FALNUM5(II)=FALNUM5(II)+DETTIME/60.
           GO TO 1032
         ENDIF
         1031 CONTINUE
         1032 CONTINUE
         FALNUM3(II)=((YR-1)*12)+K
    IF(AGTANK.AND.CRADLE)THEN
    IF((AGCONT(L).EQ.K).OR.(AGTANK.AND.(.NOT.CRADLE))) THEN
                 TEMP=TSURF+SURF+AGCONFR*LKREL
          CALL CLENUP(TEMP)
    TSURF=0
    SURF=0
          LKREL=(1-AGCONFR)*LKREL
       AGLEAK=LKREL+AGLEAK
        ELSE
     LKREL=LKREL+TSURF+SURF
         CALL CLENUP(LKREL)
    TSURF=0
    SURF=0
           LKREL=0.
        ENDIF
      ELSE
    IF((UGCONT(L).EQ.K).OR.NOSECON.OR.(.NOT.VAULT)) THEN
                  TEMP=TSURF+SURF+UGCONFR*LKREL
           CALL CLENUP(TEMP)
     TSURF=0
     SURF=0
           LKREL=(1-UGCONFR)*LKREL
        UGLEAK=LKREL+UGLEAK
         ELSE
      LKREL=LKREL+TSURF+SURF
          CALL CLENUP(LKREL)
     TSURF=0
     SURF=0
                 LKREL=0.
         ENDIF
     ENDIF
         TKVOL(L)=TKVOL(L)+LKREL
     MONREL=LKREL+MONREL
     DETECT=.FALSE.
        IF (((MAX(DETTIME,TREMDT))-TREMDT).NE.0) THEN
          TREMDT=DETTIME
           TREMRT=TKLKRT(L)
        ENDIF
       IF(YRO.NE.0.AND.IYRNUM.LT.YRO)TANKREP=.TRUE.
      CALL FIX(DLAB,K,YR,L,1)
   CALL VAPZERO(3,1)
       DO 818 LL=1,NPI
     IF(WLDEFVL(LL).GT.0) CALL FIX(DLAB,K,YR,LL,7)
        IF(RPWLVOL(LL).GT.0) CALL FIX(DLAB,K,YR,LL,10)
     IF(GKDEFVL(LL).GT.0) CALL FIX(DLAB,K,YR,LL,8)
      CALL FIX(DLAB,K,YR,LL,9)
        818 CONTINUE
     IF(TKDEFVL(L).GT.0) CALL FIX(DLAB,K,YR,L,3)
        IF(RPTKVOL(L).GT.0) CALL FIX(DLAB,K,YR,L,2)
  ENDIF
206 CONTINUE
      LKREL=0
   5843 CONTINUE
SKIP=.FALSE.
MSKIP=.FALSE.
  IF(TSURF.LE.0)TPRSURF=0
  TTOTAL=(TSURF-TPRSURF)+(TSUB-TPRSUB)
*  INVENTORY CONTROL
   IF(INVCNTL)THEN
      MOVOLUM=FILLVOL(1)*FILLFR(1)*DAYMO
      IF(WEEKINV)THEN
         RELFRAC=0.25
         DETVOL=WINVLIM*TNKCAP(1)
        ELSE
        SKIP=.TRUE.
      ENDIF
  262 CONTINUE
    IF(RELFRAC.EQ.1.)DLAB='MI'
    IF(RELFRAC.EQ.0.25)DLAB='WI'
   IF(.NOT.SKIP)THEN
      IF(TTOTAL*RELFRAC.GT.DETVOL)THEN
       DO 611 L=1,NPI
   IF((PIPDEF(L).EQ.K).OR.(RUPPIP(L).EQ.K).OR.(PIPLK(L).EQ.K)
+     .OR.(GSKLK(L).EQ.K).OR.(WLDDEF(L).EQ.K).OR.(GSKDEF(L)
+       .EQ.K).OR.(RUPWLD(L).EQ.K))THEN
```

```
  IF (PIPCONT (L) .EQ.K) THEN
    TSURF=TSURF-PAGFRAC* (PILKVOL (L) +RPPIVOL (L) +
      PIDEFVL (L) +GKLKVOL (L) +WLDEFVL (L) +
      GKDEFVL (L) +RPWLVOL (L))

    SURF=SURF+PAGFRAC*RELFRAC* (PILKVOL (L) +RPPIVOL (L) +
      PIDEFVL (L) +GKLKVOL (L) +WLDEFVL (L) +
      GKDEFVL (L) +RPWLVOL (L))

    TSUB=TSUB- (1-PAGFRAC) * (PILKVOL (L) +RPPIVOL (L)
    +PIDEFVL (L) +GKLKVOL (L) +
      WLDEFVL (L) +GKDEFVL (L) +RPWLVOL (L))

    SUBSURF=SUBSURF+ (1-PAGFRAC) *RELFRAC* (PILKVOL (L) +RPPIVOL (L) +
      PIDEFVL (L) +GKLKVOL (L) +WLDEFVL (L) +
      GKDEFVL (L) +RPWLVOL (L))

   ELSE
     TSURF=TSURF- (PILKVOL (L) +RPPIVOL (L) +
       PIDEFVL (L) +GKLKVOL (L) +WLDEFVL (L) +
       GKDEFVL (L) +RPWLVOL (L))

     SURF=SURF+RELFRAC* (PILKVOL (L) +RPPIVOL (L) +
      PIDEFVL (L) +GKLKVOL (L) +WLDEFVL (L) +
       GKDEFVL (L) +RPWLVOL (L))

   ENDIF
CALL VAPZERO (1,L)
IF ((PIPLK (L) .EQ.K) .OR. (RUPPIP (L) .EQ.K) .OR. (PIPDEF (L) .EQ.K)) THEN
    IF (RELFRAC.NE.1) THEN
      DO 1302 II=FALNUM,1,-1
       IF (FALNUM1 (II) .EQ. (3010+L)) THEN
         IF (FALNUM5 (II) .GT.720) THEN
             FALNUM2 (II) =FALNUM2 (II) - (1-RELFRAC) *PILKVOL (L)
             FALNUM5 (II) =FALNUM5 (II) - (1-RELFRAC) *720
         ELSEIF (FALNUM5 (II) .GT.168) THEN
FALNUM2 (II) =PILKVOL (L) *168/FALNUM5 (II)
FALNUM5 (II) =168
         ELSE
         ENDIF
         GO TO 1312
       ENDIF
       1302 CONTINUE
       1312 CONTINUE
      ENDIF
 CALL FIX (DLAB,K,YR,L,4)
ENDIF
IF (PIPDEF (L) .EQ.K) THEN
    IF (RELFRAC.NE.1) THEN
      DO 1300 II=FALNUM,1,-1
       IF (FALNUM1 (II) .EQ. (1010+L)) THEN
         IF (FALNUM5 (II) .GT.720) THEN
             FALNUM2 (II) =FALNUM2 (II) - (1-RELFRAC) *PIDEFVL (L)
             FALNUM5 (II) =FALNUM5 (II) - (1-RELFRAC) *720
         ELSEIF (FALNUM5 (II) .GT. 168) THEN
FALNUM2 (II) =PIDEFVL (L) *168/FALNUM5 (II)
FALNUM5 (II) =168
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```
          ELSE
          ENDIF
          GO TO 1310
        ENDIF
        1300 CONTINUE
        1310 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,6)
ENDIF
IF(RUPPIP(L).EQ.K)THEN
    IF(RELFRAC.NE.1)THEN
      DO 1301 II=FALNUM,1,-1
        IF(FALNUM1(II).EQ.(2010+L))THEN
          IF(FALNUM5(II).GT.720)THEN
              FALNUM2(II)=FALNUM2(II)-(1-RELFRAC)*RPPIVOL(L)
              FALNUM5(II)=FALNUM5(II)-(1-RELFRAC)*720
          ELSEIF(FALNUM5(II).GT.168)THEN
FALNUM2(II)=RPPIVOL(L)*168/FALNUM5(II)
FALNUM5(II)=168
          ELSE
          ENDIF
          GO TO 1311
        ENDIF
        1301 CONTINUE
        1311 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,5)
ENDIF
IF(GSKLK(L).NE.0)THEN
 IF(GSKLK(L).EQ.K)THEN
    IF(RELFRAC.NE.1)THEN
      DO 1303 II=FALNUM,1,-1
        IF(FALNUM1(II).EQ.(3050+L))THEN
          IF(FALNUM5(II).GT.720)THEN
              FALNUM2(II)=FALNUM2(II)-(1-RELFRAC)*GKLKVOL(L)
              FALNUM5(II)=FALNUM5(II)-(1-RELFRAC)*720
          ELSEIF(FALNUM5(II).GT.168)THEN
FALNUM2(II)=GKLKVOL(L)*168/FALNUM5(II)
FALNUM5(II)=168
          ELSE
          ENDIF
          GO TO 1313
        ENDIF
        1303 CONTINUE
        1313 CONTINUE
      ENDIF
 ENDIF
 CALL FIX(DLAB,K,YR,L,9)
ENDIF
IF(WLDDEF(L).EQ.K)THEN
    IF(RELFRAC.NE.1)THEN
      DO 1304 II=FALNUM,1,-1
        IF(FALNUM1(II).EQ.(1040+L))THEN
          IF(FALNUM5(II).GT.720)THEN
              FALNUM2(II)=FALNUM2(II)-(1-RELFRAC)*WLDEFVL(L)
              FALNUM5(II)=FALNUM5(II)-(1-RELFRAC)*720
          ELSEIF(FALNUM5(II).GT.168)THEN
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FALNUM2(II)=WLDEFVL(L)*168/FALNUM5(II)
FALNUM5(II)=168
         ELSE
         ENDIF
         GO TO 1314
       ENDIF
       1304 CONTINUE
       1314 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,7)
ENDIF
IF(RUPWLD(L).EQ.K)THEN
    IF(RELFRAC.NE.1)THEN
      DO 1305 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(2040+L))THEN
         IF(FALNUM5(II).GT.720)THEN
            FALNUM2(II)=FALNUM2(II)-(1-RELFRAC)*RPWLVOL(L)
            FALNUM5(II)=FALNUM5(II)-(1-RELFRAC)*720
         ELSEIF(FALNUM5(II).GT.168)THEN
FALNUM2(II)=RPWLVOL(L)*168/FALNUM5(II)
FALNUM5(II)=168
         ELSE
         ENDIF
         GO TO 1315
       ENDIF
       1305 CONTINUE
       1315 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,10)
ENDIF
IF(GSKDEF(L).EQ.K)THEN
    IF(RELFRAC.NE.1)THEN
      DO 1306 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(1050+L))THEN
         IF(FALNUM5(II).GT.720)THEN
            FALNUM2(II)=FALNUM2(II)-(1-RELFRAC)*GKDEFVL(L)
            FALNUM5(II)=FALNUM5(II)-(1-RELFRAC)*720
         ELSEIF(FALNUM5(II).GT.168)THEN
FALNUM2(II)=GKDEFVL(L)*168/FALNUM5(II)
FALNUM5(II)=168
         ELSE
         ENDIF
         GO TO 1316
       ENDIF
       1306 CONTINUE
       1316 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,8)
ENDIF
   ENDIF
611 CONTINUE
DO 7611 L=1,NTK
IF((TNKDEF(L).EQ.K).OR.(TNKLK(L).EQ.K).OR.(RUPTNK(L).EQ.K))THEN
       IF(((AGCONT(L).EQ.K).OR.(.NOT.CRADLE)).AND.AGTANK)THEN
       TSURF=TSURF-AGCONFR*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
       TSUB=TSUB-(1-AGCONFR)*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
SUBSURF=SUBSURF+(1-AGCONFR)*RELFRAC*(TKDEFVL(L)+TKLKVOL(L)+
+RPTKVOL(L))
  SURF=SURF+AGCONFR*RELFRAC*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
        ELSEIF((UGCONT(L).EQ.K).AND..NOT.AGTANK)THEN
     TSURF=TSURF-UGCONFR*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
      TSUB=TSUB-(1-UGCONFR)*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
SUBSURF=SUBSURF+(1-UGCONFR)*RELFRAC*(TKDEFVL(L)+TKLKVOL(L)+
+RPTKVOL(L))
   SURF=SURF+UGCONFR*RELFRAC*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
        ELSEIF(VAULT.OR.LINER)THEN
            TSURF=TSURF-(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
            SURF=SURF+RELFRAC*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
*      NO CONTAINMENT FAILURE-ALL SURFACE SPILL
        ELSE
          IF(UGTANK.OR.IGTANK)THEN
             TSUB=TSUB-(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
       SUBSURF=SUBSURF+RELFRAC*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
            ELSE
             TSURF=TSURF-(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
        SURF=SURF+RELFRAC*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
          ENDIF
        ENDIF
 CALL VAPZERO(3,1)
IF((TNKDEF(L).EQ.K.OR.TNKLK(L).EQ.K.OR.RUPTNK(L).EQ.K)
+.AND.YRO.NE.O.AND.IYRNUM.LT.YRO)TANKREP=.TRUE.
        IF(TNKDEF(L).EQ.K)THEN
    IF(RELFRAC.NE.1)THEN
     DO 1307 II=FALNUM,1,-1
      IF(FALNUM1(II).EQ.1030+L)THEN
        IF(FALNUM5(II).GT.720)THEN
           FALNUM2(II)=FALNUM2(II)-(1-RELFRAC)*TKDEFVL(L)
           FALNUM5(II)=FALNUM5(II)-(1-RELFRAC)*720
        ELSEIF(FALNUM5(II).GT.168)THEN
FALNUM2(II)=TKDEFVL(L)*168/FALNUM5(II)
FALNUM5(II)=168
        ELSE
        ENDIF
        GO TO 1317
      ENDIF
      1307 CONTINUE
      1317 CONTINUE
     ENDIF
 CALL FIX(DLAB,K,YR,L,3)
        ENDIF
        IF(RUPTNK(L).EQ.K)THEN
    IF(RELFRAC.NE.1)THEN
     DO 1308 II=FALNUM,1,-1
      IF(FALNUM1(II).EQ.2030+L)THEN
        IF(FALNUM5(II).GT.720)THEN
           FALNUM2(II)=FALNUM2(II)-(1-RELFRAC)*RPTKVOL(L)
           FALNUM5(II)=FALNUM5(II)-(1-RELFRAC)*720
        ELSEIF(FALNUM5(II).GT.168)THEN
FALNUM2(II)=RPTKVOL(L)*168/FALNUM5(II)
FALNUM5(II)=168
        ELSE
        ENDIF
        GO TO 1318
      ENDIF
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       1308 CONTINUE
       1318 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,2)
       ENDIF
      IF(TNKLK(L).NE.0)THEN
 IF(TNKLK(L).EQ.K)THEN
    IF(RELFRAC.NE.1)THEN
      DO 1309 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.3030+L)THEN
         IF(FALNUM5(II).GT.720)THEN
             FALNUM2(II)=FALNUM2(II)-(1-RELFRAC)*TKLKVOL(L)
             FALNUM5(II)=FALNUM5(II)-(1-RELFRAC)*720
         ELSEIF(FALNUM5(II).GT.168)THEN
FALNUM2(II)=TKLKVOL(L)*168/FALNUM5(II)
FALNUM5(II)=168
         ELSE
         ENDIF
         GO TO 1319
       ENDIF
       1309 CONTINUE
       1319 CONTINUE
      ENDIF
   ENDIF
 CALL FIX(DLAB,K,YR,L,1)
     ENDIF
ENDIF
7611 CONTINUE
SURF=SURF+TSURF
TSURF=0
  CALL CLENUP(SURF)
  SURF=0
      PRSURF=0
   ENDIF
   ENDIF
   IF(WEEKINV)THEN
      IF(TTOTAL*RELFRAC.GT.DETVOL) GO TO 263
   ENDIF
   IF(.NOT.MSKIP)THEN
   IF(MONINV)THEN
      SKIP=.FALSE.
      INVVOL=MOVOLUM-MONREL
      DETVOL=MINVLIM*INVVOL
      RELFRAC=1.0
      MSKIP=.TRUE.
      GO TO 262
   ENDIF
  ENDIF
 263 CONTINUE
ENDIF
* VAPOR WELL DETECTION
*TOTAL VAPOR WELL CONTRIBUTION
IF(MONMETH(5)) THEN
IF(.NOT.VAPDET) THEN
  IF(.NOT.VAPFLG)THEN
    VAPCONC=0
    DO 901 L=1,NPI
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      IF(PIPDEF(L).EQ.K) THEN
        DO 902 II=FALNUM,1,-1
           IF(FALNUM1(II).EQ.(1010+L))GO TO 921
        902 CONTINUE
921     IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
           ((4-L)/L)**3))THEN
             Z=(VAPWDIS(1)/3.28)/(4*DIFF2*3600*
                FALNUM5(II))**0.5
        CALL ERF(Z,FOFZ,2)
        VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
        GO TO 973
        ENDIF
      ENDIF
      IF(RUPPIP(L).EQ.K) THEN
        DO 903 II=FALNUM,1,-1
           IF(FALNUM1(II).EQ.(2010+L))GO TO 922
        903 CONTINUE
922     IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
           ((4-L)/L)**3))THEN
             Z=(VAPWDIS(1)/3.28)/(4*DIFF2*3600*
                FALNUM5(II))**0.5
        CALL ERF(Z,FOFZ,2)
        VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
      GO TO 973
        ENDIF
        ENDIF
      IF(PIPLK(L).EQ.K) THEN
        DO 904 II=FALNUM,1,-1
           IF(FALNUM1(II).EQ.(3010+L))GO TO 923
        904 CONTINUE
923     IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
           ((4-L)/L)**3))THEN
             Z=(VAPWDIS(1)/3.28)/(4*DIFF2*3600*
                FALNUM5(II))**0.5
        CALL ERF(Z,FOFZ,2)
        VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
        ENDIF
      ENDIF
973   IF(GSKLK(L).EQ.K) THEN
        DO 905 II=FALNUM,1,-1
           IF(FALNUM1(II).EQ.(3050+L))GO TO 924
        905 CONTINUE
924     IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
           (3)**3))THEN
             Z=(VAPWDIS(3)/3.28)/(4*DIFF1*3600*
                FALNUM5(II))**0.5
        CALL ERF(Z,FOFZ,2)
        VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
        ENDIF
      ENDIF
      IF(WLDDEF(L).EQ.K) THEN
        DO 906 II=FALNUM,1,-1
           IF(FALNUM1(II).EQ.(1040+L))GO TO 925
        906 CONTINUE
925     IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
           (3)**3))THEN
             Z=(VAPWDIS(3)/3.28)/(4*DIFF1*3600*
46435+             FALNUM5(II))**0.5
46440       CALL ERF(Z,FOFZ,2)
46445       VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
46450       ENDIF
46455     ENDIF
46460     IF(RUPWLD(L).EQ.K) THEN
46465       DO 915 II=FALNUM,1,-1
46470         IF(FALNUM1(II).EQ.(2040+L))GO TO 926
46475       915 CONTINUE
46480 926   IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
46485+        (3)**3))THEN
46490           Z=(VAPWDIS(3)/3.28)/(4*DIFF1*3600*
46495+             FALNUM5(II))**0.5
46500       CALL ERF(Z,FOFZ,2)
46505       VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
46510       ENDIF
46515     ENDIF
46520     IF(GSKDEF(L).EQ.K) THEN
46525       DO 916 II=FALNUM,1,-1
46530         IF(FALNUM1(II).EQ.(1050+L))GO TO 927
46535       916 CONTINUE
46540 927   IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
46545+        (3)**3))THEN
46550           Z=(VAPWDIS(3)/3.28)/(4*DIFF1*3600*
46555+             FALNUM5(II))**0.5
46560       CALL ERF(Z,FOFZ,2)
46565       VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
46570       ENDIF
46575     ENDIF
46580     IF(PMPLK(L).EQ.K) THEN
46585       DO 917 II=FALNUM,1,-1
46590         IF(FALNUM1(II).EQ.(3020+L))GO TO 928
46595       917 CONTINUE
46600 928   IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
46605+        (2)**3))THEN
46610           Z=(VAPWDIS(2)/3.28)/(4*DIFF2*3600*
46615+             FALNUM5(II))**0.5
46620       CALL ERF(Z,FOFZ,2)
46625       VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
46630       ENDIF
46635     ENDIF
46640     901 CONTINUE
46645    DO 9010 L=1,NTK
46650     IF(TNKDEF(L).EQ.K) THEN
46655       DO 918 II=FALNUM,1,-1
46660         IF(FALNUM1(II).EQ.1030+L)GO TO 929
46665       918 CONTINUE
46670 929   IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
46675+        (3)**3))THEN
46680           Z=(VAPWDIS(3)/3.28)/(4*DIFF1*3600*
46685+             FALNUM5(II))**0.5
46690       CALL ERF(Z,FOFZ,2)
46695       VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
46700       ENDIF
46705     ENDIF
46710     IF(TNKLK(L).EQ.K) THEN
46715       DO 919 II=FALNUM,1,-1
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        IF(FALNUM1(II).EQ.3030+L)GO TO 930
      919 CONTINUE
930   IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
        (3)**3))THEN
          Z=(VAPWDIS(3)/3.28)/(4*DIFF1*3600*
             FALNUM5(II))**0.5
      CALL ERF(Z,FOFZ,2)
      VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
      ENDIF
    ENDIF
    IF(RUPTNK(L).EQ.K) THEN
      DO 920 II=FALNUM,1,-1
        IF(FALNUM1(II).EQ.2030+L)GO TO 931
      920 CONTINUE
931   IF(FALNUM2(II).GT.(.0313*POR*VAPWDIS
        (3)**3))THEN
          Z=(VAPWDIS(3)/3.28)/(4*DIFF1*3600*
             FALNUM5(II))**0.5
      CALL ERF(Z,FOFZ,2)
      VAPCONC=VAPCONC+(VAPRESS*(1-FOFZ))
      ENDIF
    ENDIF
    DLAB='TV'
    IF(VAPCONC.GE.LOWER)VAPDET=.TRUE.
   9010 CONTINUE
    ENDIF
 ENDIF
ENDIF
IF(VAPDET) THEN
  RELFRAC=1.0
  TKLKVAP=0
  TKRPVAP=0
  TKDFVAP=0
  DO 940 L=1,NPI
 CALL VAPZERO(1,L)
   PMPVAP(L)=0
   IF((PIPDEF(L).EQ.K).OR.(RUPPIP(L).EQ.K).OR.(PIPLK(L).EQ.K)
      .OR.(GSKLK(L).EQ.K).OR.(WLDDEF(L).EQ.K).OR.(GSKDEF(L)
        .EQ.K).OR.(RUPWLD(L).EQ.K))THEN
  IF(PIPCONT(L).EQ.K)THEN
    TSURF=TSURF-PAGFRAC*(PILKVOL(L)+RPPIVOL(L)+
      PIDEFVL(L)+GKLKVOL(L)+WLDEFVL(L)+
      GKDEFVL(L)+RPWLVOL(L))

    SURF=SURF+PAGFRAC*(PILKVOL(L)+RPPIVOL(L)+
      PIDEFVL(L)+GKLKVOL(L)+WLDEFVL(L)+
      GKDEFVL(L)+RPWLVOL(L))

    TSUB=TSUB-(1-PAGFRAC)*(PILKVOL(L)+RPPIVOL(L)
    +PIDEFVL(L)+GKLKVOL(L)+
      WLDEFVL(L)+GKDEFVL(L)+RPWLVOL(L))

    SUBSURF=SUBSURF+(1-PAGFRAC)*(PILKVOL(L)+RPPIVOL(L)+
      PIDEFVL(L)+GKLKVOL(L)+WLDEFVL(L)+
      GKDEFVL(L)+RPWLVOL(L))

   ELSE
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47005        TSURF=TSURF-(PILKVOL(L)+RPPIVOL(L)+
47010+          PIDEFVL(L)+GKLKVOL(L)+WLDEFVL(L)+
47015+          GKDEFVL(L)+RPWLVOL(L))
47020
47025        SURF=SURF+(PILKVOL(L)+RPPIVOL(L)+
47030+         PIDEFVL(L)+GKLKVOL(L)+WLDEFVL(L)+
47035+          GKDEFVL(L)+RPWLVOL(L))
47040
47045      ENDIF
47050 IF((PIPLK(L).EQ.K).OR.(PIPDEF(L).EQ.K).OR.(RUPPIP(L).EQ.K))
47055+CALL FIX(DLAB,K,YR,L,4)
47060 IF(PIPDEF(L).EQ.K)CALL FIX(DLAB,K,YR,L,6)
47065 IF(RUPPIP(L).EQ.K)CALL FIX(DLAB,K,YR,L,5)
47070 IF(GSKLK(L).NE.O)CALL FIX(DLAB,K,YR,L,9)
47075 IF(WLDDEF(L).EQ.K)CALL FIX(DLAB,K,YR,L,7)
47080 IF(RUPWLD(L).EQ.K)CALL FIX(DLAB,K,YR,L,10)
47085 IF(GSKDEF(L).EQ.K)CALL FIX(DLAB,K,YR,L,8)
47090      ENDIF
47095    IF(PMPLK(L).EQ.K)THEN
47100           IF(PIPCONT(L).EQ.K)THEN
47105                  TSURF=TSURF-PAGFRAC*(PMLKVOL(L))
47110                  TSUB=TSUB-(1-PAGFRAC)*(PMLKVOL(L))
47115                  SUBSURF=SUBSURF+(1-PAGFRAC)*(PMLKVOL(L))
47120                  SURF=SURF+PAGFRAC*(PMLKVOL(L))
47125              ELSE
47130*               NO CONTAINMENT FAILURE
47135                  TSURF=TSURF-(PMLKVOL(L))
47140                  SURF=SURF+(PMLKVOL(L))
47145             ENDIF
47150          PMPVAP(L)=0.
47155           PMPLK(L)=0
47160           PMLKVOL(L)=0
47165           PMLKRT(L)=0
47170         PUMPI(L)=IPUMP(L)
47175         PUMPE(L)=IPUMP(L)
47180         IF (.NOT.PMREPAR(L)) THEN
47185             CALL REPLAC(2,L)
47190               DO 1460 IJ=FALNUM,1,-1
47195                 IF(MOD(FALNUM1(IJ),100).EQ.(20+L))GO TO 1461
47200               1460 CONTINUE
47205               1461 FALNUM6(IJ)=DLAB
47210             PREMREP=.TRUE.
47215             PMREPAR(L)=.TRUE.
47220         ENDIF
47225      SURF=SURF+TSURF
47230      TSURF=0
47235   IF (SURF.GT.0) THEN
47240 SURF=SURF+TSURF
47245 TSURF=0
47250       CALL CLENUP(SURF)
47255     SURF=0
47260          PRSURF=0
47265   ENDIF
47270   ENDIF
47275       940 CONTINUE
47280 DO 9041 L=1,NTK
47285 IF((TNKDEF(L).EQ.K).OR.(TNKLK(L).EQ.K).OR.(RUPTNK(L).EQ.K))THEN
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      IF (((AGCONT (L) .EQ.K) .OR. (.NOT.CRADLE)) .AND.AGTANK) THEN
        TSURF=TSURF-AGCONFR* (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))

        TSUB=TSUB- (1-AGCONFR) * (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
    SUBSURF=SUBSURF+ (1-AGCONFR) * (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
              SURF=SURF+AGCONFR* (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
         ELSEIF ((UGCONT (L) .EQ.K) .AND..NOT.AGTANK) THEN
       TSURF=TSURF-UGCONFR* (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
      TSUB=TSUB- (1-UGCONFR) * (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
  SUBSURF=SUBSURF+ (1-UGCONFR) * (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
              SURF=SURF+UGCONFR* (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
         ELSEIF (VAULT.OR.LINER) THEN
              TSURF=TSURF- (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
              SURF=SURF+ (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
*     NO CONTAINMENT FAILURE-ALL SURFACE SPILL
         ELSE
            IF (UGTANK.OR.IGTANK) THEN
               TSUB=TSUB- (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
               SUBSURF=SUBSURF+ (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
              ELSE
               TSURF=TSURF- (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
               SURF=SURF+ (TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L))
            ENDIF
          ENDIF
 CALL VAPZERO (3,1)
IF ((TNKDEF (L) .EQ.K.OR.TNKLK (L) .EQ.K.OR.RUPTNK (L) .EQ.K)
+   .AND.YRO.NE.O.AND.IYRNUM.LT.YRO) TANKREP=.TRUE.
         IF (TNKDEF (L) .EQ.K) CALL  FIX (DLAB,K,YR,L,3)
         IF (RUPTNK (L) .EQ.K) CALL  FIX (DLAB,K,YR,L,2)
      IF (TNKLK (L) .NE.O) CALL  FIX (DLAB,K,YR,L,1)
ENDIF
9041 CONTINUE
SURF=SURF+TSURF
TSURF=O
  CALL CLENUP (SURF)
  SURF=O
      PRSURF=O
 ENDIF
*FLASHPOINT************************
IF (FALNUM.EQ.O) GO TO 1609
DO 1603 II=1,FALNUM
  IF (FALNUM3 (II) .EQ. ((YR-1) *12+K)) THEN
     POOF=POOF-43200.
     FLASHVL=TSUB
   GO TO 1602
ENDIF
1603 CONTINUE
1609 POOF=FLASHTM
   FLASHVL=O
1602 IF ((POOF.LE.O.) .AND. (FLASHVL.GE. (.0313*POR*FLASHX**3))) THEN
    POOF=FLASHTM
IF (FLASHON) THEN
  DLAB='FP'
IF (IYRNUM.GE.YRO) AGFLASH=AGFLASH+1
DO 854 L=1,NPI
   TEMPVOL=WLDEFVL (L) +GKDEFVL (L) +
+ PIDEFVL (L) +RPWLVOL (L) +GKLKVOL (1) +
47575+  RPPIVOL(L)+PILKVOL(L)
47580      IF(PIPCONT(L).EQ.K)THEN
47585         TSURF=TSURF-PAGFRAC*TEMPVOL
47590         SURF=SURF+PAGFRAC*TEMPVOL
47595         TSUB=TSUB-(1-PAGFRAC)*TEMPVOL
47600         SUBSURF=SUBSURF+(1-PAGFRAC)*TEMPVOL
47605                 ELSE
47610         TSURF=TSURF-TEMPVOL
47615         SURF=SURF+TEMPVOL
47620       ENDIF
47625  CALL VAPZERO(1,L)
47630 IF((PIPLK(L).EQ.K).OR.(PIPDEF(L).EQ.K).OR.(RUPPIP(L).EQ.K))
47635+CALL FIX(DLAB,K,YR,L,4)
47640 IF(PIPDEF(L).EQ.K)CALL FIX(DLAB,K,YR,L,6)
47645 IF(RUPPIP(L).EQ.K)CALL FIX(DLAB,K,YR,L,5)
47650   IF(GSKLK(L).NE.0) CALL FIX(DLAB,K,YR,L,9)
47655 IF(WLDDEF(L).EQ.K)CALL FIX(DLAB,K,YR,L,7)
47660 IF(GSKDEF(L).EQ.K)CALL FIX(DLAB,K,YR,L,8)
47665 IF(RUPWLD(L).EQ.K)CALL FIX(DLAB,K,YR,L,10)
47670 854 CONTINUE
47675 DO 8054 L=1,NTK
47680   TEMPVOL=TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L)
47685       IF(AGTANK)THEN
47690           IF((AGCONT(L).EQ.K).OR.(AGTANK.AND.(.NOT.CRADLE)))  THEN
47695         TSURF=TSURF-AGCONFR*TEMPVOL
47700         SURF=SURF+AGCONFR*TEMPVOL
47705         TSUB=TSUB-(1-AGCONFR)*TEMPVOL
47710         SUBSURF=SUBSURF+(1-AGCONFR)*TEMPVOL
47715        ELSE
47720         TSURF=TSURF-TEMPVOL
47725         SURF=SURF+TEMPVOL
47730        ENDIF
47735      ELSE
47740*UGTANK.OR.IGTANK
47745   IF((UGCONT(L).EQ.K).OR.NOSECON.OR.(.NOT.VAULT))THEN
47750         TSURF=TSURF-UGCONFR*TEMPVOL
47755         SURF=SURF+UGCONFR*TEMPVOL
47760         TSUB=TSUB-(1-UGCONFR)*TEMPVOL
47765         SUBSURF=SUBSURF+(1-UGCONFR)*TEMPVOL
47770   ELSE
47775         TSURF=TSURF-TEMPVOL
47780         SURF=SURF+TEMPVOL
47785   ENDIF
47790        ENDIF
47795   CALL VAPZERO(3,1)
47800 IF((TNKDEF(L).EQ.K.OR.TNKLK(L).EQ.K.OR.RUPTNK(L).EQ.K)
47805+   .AND.YRO.NE.0.AND.IYRNUM.LT.YRO)TANKREP=.TRUE.
47810          IF((TNKLK(L).EQ.K).OR.(TNKDEF(L).EQ.K).OR.
47815+      (RUPTNK(L).EQ.K))CALL FIX(DLAB,K,YR,L,1)
47820          IF(TNKDEF(L).EQ.K)CALL FIX(DLAB,K,YR,L,3)
47825          IF(RUPTNK(L).EQ.K)CALL FIX(DLAB,K,YR,L,2)
47830   8054 CONTINUE
47835    SURF=SURF+TSURF
47840    TSURF=0
47845  IF (SURF.GT.0) THEN
47850 SURF=SURF+TSURF
47855 TSURF=0
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47860      CALL CLENUP(SURF)
47865    SURF=0
47870         PRSURF=0
47875  ENDIF
47880 ELSE
47885     IF((IYRNUM.GE.YRO).AND.(.NOT.FLREMED))THEN
47890         AGFLASH=AGFLASH+1
47895         FLREMED=.TRUE.
47900     ENDIF
47905 ENDIF
47910 ENDIF
47915    IF(MOD(K-1,3).EQ.0)THEN
47920    QUARSUB=0
47925    ENDIF
47930 SUBSURF=UGRUPT+UGLEAK+SUBSURF+AGRUPT+AGLEAK
47935    QUARSUB=QUARSUB+SUBSURF-PRSUB+(TSUB-TPRSUB)
47940*  CALL TRANS(QUARSUB,INICONC,DETCONC)
47945****VISUAL INSPECTION
47950      IF(INSPECT(2).OR.WEEKINS)THEN
47955        DLAB='VI'
47960         DO 61 L=1,NPI
47965      IF((PIPDEF(L).EQ.K).OR.(RUPPIP(L).EQ.K).OR.(PIPLK(L).EQ.K)
47970+          .OR.(GSKLK(L).EQ.K).OR.(WLDDEF(L).EQ.K).OR.(GSKDEF(L)
47975+          .EQ.K).OR.(RUPWLD(L).EQ.K))THEN
47980                        IF(AGPIPE)THEN
47985 IFRAC=0.
47990 IF(WEEKINS)THEN
47995*   WEEKLY INSPECTION
48000    NOOFDAY=MOFRAC*30.
48005    DO 7065 KK=1,4
48010        IF((MOFRAC*30.).LE.7*KK)THEN
48015            IFRAC=IFRAC+(NOOFDAY/(MOFRAC*30.))
48020            NOOFDAY=0.
48025        ELSE
48030            IFRAC=IFRAC+(7./(MOFRAC*30.))
48035            NOOFDAY=NOOFDAY-7.
48040        ENDIF
48045        PIPINSF(2)=FNB(PIPINSF(1))
48050        IF(PIPINSF(2).EQ.0)GO TO 7066
48055    7065 CONTINUE
48060* INSPECTION FAILURE
48065    GO TO 7067
48070   7066 CONTINUE
48075 ELSE
48080*   MONTHLY INSPECTION
48085    IFRAC=1.0
48090    PIPINSF(2)=FNB(PIPINSF(1))
48095*   INSPECTION FAILURE
48100    IF(PIPINSF(2).EQ.1)GO TO 7067
48105 ENDIF
48110   IF(PIPCONT(L).EQ.K)THEN
48115     TSURF=TSURF-PAGFRAC*(PILKVOL(L)+RPPIVOL(L)+
48120+        PIDEFVL(L)+GKLKVOL(L)+WLDEFVL(L)+
48125+        GKDEFVL(L)+RPWLVOL(L))
48130
48135     SURF=SURF+PAGFRAC*(PILKVOL(L)+RPPIVOL(L)+
48140+        PIDEFVL(L)+GKLKVOL(L)+WLDEFVL(L)+
48145+      GKDEFVL(L)+RPWLVOL(L))*IFRAC
48150
48155     TSUB=TSUB-(1-PAGFRAC)*(PILKVOL(L)+RPPIVOL(L)
48160+    +PIDEFVL(L)+GKLKVOL(L)+
48165+      WLDEFVL(L)+GKDEFVL(L)+RPWLVOL(L))
48170
48175     SUBSURF=SUBSURF+(1-PAGFRAC)*(PILKVOL(L)+RPPIVOL(L)+
48180+      PIDEFVL(L)+GKLKVOL(L)+WLDEFVL(L)+
48185+      GKDEFVL(L)+RPWLVOL(L))*IFRAC
48190
48195    ELSE
48200      TSURF=TSURF-(PILKVOL(L)+RPPIVOL(L)+
48205+       PIDEFVL(L)+GKLKVOL(L)+WLDEFVL(L)+
48210+       GKDEFVL(L)+RPWLVOL(L))
48215
48220      SURF=SURF+(PILKVOL(L)+RPPIVOL(L)+
48225+      PIDEFVL(L)+GKLKVOL(L)+WLDEFVL(L)+
48230+       GKDEFVL(L)+RPWLVOL(L))*IFRAC
48235
48240    ENDIF
48245    SURF=SURF+TSURF
48250    TSURF=0
48255 TPRSURF=0
48260 PRSURF=0
48265 SURF=0
48270  IF (SURF.GT.0) THEN
48275 SURF=SURF+TSURF
48280 TSURF=0
48285     CALL CLENUP(SURF)
48290   SURF=0
48295       PRSURF=0
48300     TPRSURF=0
48305    ENDIF
48310 CALL VAPZERO(1,L)
48315   IF(PMPLK(L).EQ.K)THEN
48320    IF(PIPCONT(L).EQ.K)THEN
48325              TSURF=TSURF-PAGFRAC*(PMLKVOL(L))
48330              TSUB=TSUB-(1-PAGFRAC)*(PMLKVOL(L))
48335              SUBSURF=SUBSURF+(1-PAGFRAC)*(PMLKVOL(L))*IFRAC
48340              SURF=SURF+PAGFRAC*(PMLKVOL(L))*IFRAC
48345           ELSE
48350*             NO CONTAINMENT FAILURE
48355              TSURF=TSURF-(PMLKVOL(L))
48360              SURF=SURF+(PMLKVOL(L))*IFRAC
48365          ENDIF
48370       PMPVAP(L)=0.
48375        PMPLK(L)=0
48380        PMLKVOL(L)=0
48385        PMLKRT(L)=0
48390      PUMPI(L)=IPUMP(L)
48395      PUMPE(L)=IPUMP(L)
48400      IF (.NOT.PMREPAR(L)) THEN
48405         CALL REPLAC(2,L)
48410           DO 1092 IJ=FALNUM,1,-1
48415             IF(FALNUM1(IJ).EQ.(3020+L))GO TO 1158
48420           1092 CONTINUE
48425           1158 FALNUM6(IJ)=DLAB
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         PREMREP=.TRUE.
         PMREPAR(L)=.TRUE.
      ENDIF
   SURF=SURF+TSURF
   TSURF=0
 IF (SURF.GT.0) THEN
SURF=SURF+TSURF
TSURF=0
    CALL CLENUP(SURF)
  SURF=0
      PRSURF=0
 ENDIF
 ENDIF
IF((PIPLK(L).EQ.K).OR.(PIPDEF(L).EQ.K).OR.(RUPPIP(L).EQ.K))THEN
    IF(IFRAC.NE.1)THEN
      DO 11402 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(3010+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-IFRAC)*PILKVOL(L)
          IF(FALNUM5(II).GE.720)THEN
            FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*720.
          ELSEIF(L.NE.1)THEN
 FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*PILKVOL(L)/(PILKRT(L)
+  *DISCFR(L)*DISCTIM(L)/24.)
          ELSE
 FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*PILKVOL(L)/(PILKRT(L)
+            *FILLFR(L)*FILLTIM(L)/24.)
          ENDIF
         GO TO 11412
       ENDIF
       11402 CONTINUE
       11412 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,4)
ENDIF
IF(PIPDEF(L).EQ.K)THEN
    IF(IFRAC.NE.1)THEN
      DO 11400 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(1010+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-IFRAC)*PIDEFVL(L)
          IF(FALNUM5(II).GE.720)THEN
            FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*720.
          ELSEIF(L.NE.1)THEN
    FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*PIDEFVL(L)/(PIDEFRT(L)
+   *DISCFR(L)*DISCTIM(L)/24.)
          ELSE
    FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*PIDEFVL(L)/(PIDEFRT(L)
+            *FILLFR(L)*FILLTIM(L)/24.)
          ENDIF
         GO TO 11410
       ENDIF
       11400 CONTINUE
       11410 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,6)
ENDIF
IF(RUPPIP(L).EQ.K)THEN
    IF(IFRAC.NE.1)THEN
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      DO 11401 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(2010+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-IFRAC)*RPPIVOL(L)
          IF(FALNUM5(II).GE.720)THEN
            FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*720.
          ELSEIF(L.NE.1)THEN
 FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*RPPIVOL(L)/(RPPIRT(L)
+   *DISCFR(L)*DISCTIM(L)/24.)
          ELSE
 FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*RPPIVOL(L)/(RPPIRT(L)
+            *FILLFR(L)*FILLTIM(L)/24.)
          ENDIF
         GO TO 11411
       ENDIF
       11401 CONTINUE
       11411 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,5)
ENDIF
IF(GSKLK(L).NE.0)THEN
 IF(GSKLK(L).EQ.K)THEN
    IF(IFRAC.NE.1)THEN
      DO 11403 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(3050+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-IFRAC)*GKLKVOL(L)
          IF(FALNUM5(II).GE.720)THEN
            FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*720.
          ELSEIF((L.NE.1).OR.((L.EQ.1).AND.(FRACTUG.LT..5)))THEN
 FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*GKLKVOL(L)/(60.*GKLKRT(L)*
+TANKTIM(L-1+1/L-L/5))
          ELSE
 FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*GKLKVOL(L)/(GKLKRT(L)
+            *FILLFR(L)*FILLTIM(L)/24.)
          ENDIF
         GO TO 11413
       ENDIF
      11403 CONTINUE
      11413 CONTINUE
      ENDIF
 ENDIF
 CALL FIX(DLAB,K,YR,L,9)
ENDIF
IF(GSKDEF(L).EQ.K)THEN
    IF(IFRAC.NE.1)THEN
      DO 11406 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(1050+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-IFRAC)*GKDEFVL(L)
          IF(FALNUM5(II).GE.720)THEN
            FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*720.
          ELSEIF((L.NE.1).OR.((L.EQ.1).AND.(FRACTUG.LT..5)))THEN
  FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*GKDEFVL(L)/(60.*GKDEFRT(L)
+ *TANKTIM(L-1+1/L-L/5))
          ELSE
  FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*GKDEFVL(L)/(GKDEFRT(L)
+            *FILLFR(L)*FILLTIM(L)/24.)
          ENDIF
         GO TO 11416
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        ENDIF
       11406 CONTINUE
       11416 CONTINUE
       ENDIF
  CALL FIX(DLAB,K,YR,L,8)
 ENDIF
 IF(WLDDEF(L).EQ.K)THEN
      IF(IFRAC.NE.1)THEN
       DO 11404 II=FALNUM,1,-1
        IF(FALNUM1(II).EQ.(1040+L))THEN
              FALNUM2(II)=FALNUM2(II)-(1-IFRAC)*WLDEFVL(L)
           IF(FALNUM5(II).GE.720)THEN
             FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*720.
           ELSEIF((L.NE.1).OR.((L.EQ.1).AND.(FRACTUG.LT..5)))THEN
  FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*WLDEFVL(L)/(60.*WLDEFRT(L)
+  *TANKTIM(L-1+1/L-L/5))
           ELSE
  FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*WLDEFVL(L)/(WLDEFRT(L)
+            *FILLFR(L)*FILLTIM(L)/24.)
           ENDIF
          GO TO 11414
        ENDIF
       11404 CONTINUE
       11414 CONTINUE
       ENDIF
  CALL FIX(DLAB,K,YR,L,7)
 ENDIF
 IF(RUPWLD(L).EQ.K)THEN
      IF(IFRAC.NE.1)THEN
       DO 11405 II=FALNUM,1,-1
        IF(FALNUM1(II).EQ.(2040+L))THEN
              FALNUM2(II)=FALNUM2(II)-(1-IFRAC)*RPWLVOL(L)
           IF(FALNUM5(II).GE.720)THEN
             FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*720.
           ELSEIF((L.NE.1).OR.((L.EQ.1).AND.(FRACTUG.LT..5)))THEN
  FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*RPWLVOL(L)/(60.*RPWLRT(L)
+   *TANKTIM(L-1+1/L-L/5))
           ELSE
  FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*RPWLVOL(L)/(RPWLRT(L)
+            *FILLFR(L)*FILLTIM(L)/24.)
           ENDIF
          GO TO 11415
        ENDIF
       11405 CONTINUE
       11415 CONTINUE
       ENDIF
  CALL FIX(DLAB,K,YR,L,10)
 ENDIF
 ENDIF
    ENDIF
 7067 CONTINUE
 61 CONTINUE
 DO 6010 L=1,NTK
 IF((TNKDEF(L).EQ.K).OR.(TNKLK(L).EQ.K).OR.(RUPTNK(L).EQ.K))THEN
       IF((AGTANK.AND.CRADLE).OR.(VAULT.AND.UGTANK))THEN
*            OPTIONS THAT CAN BE VISUALLY INSPECTED
 IFRAC=0.
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IF(WEEKINS)THEN
   NOOFDAY=MOFRAC*30.
   DO 8065 KK=1,4
      IF((MOFRAC*30.).LE.7*KK)THEN
         IFRAC=IFRAC+(NOOFDAY/(MOFRAC*30.))
         NOOFDAY=0.
      ELSE
         IFRAC=IFRAC+(7./(MOFRAC*30.))
         NOOFDAY=NOOFDAY-7.
      ENDIF
      TNKINSF(2)=FNB(TNKINSF(1))
      IF(TNKINSF(2).EQ.0)GO TO 8066
   8065 CONTINUE
* INSPECTION FAILURE
   GO TO 8067
  8066 CONTINUE
ELSE
*  MONTHLY INSPECTION
   IFRAC=1.0
   TNKINSF(2)=FNB(TNKINSF(1))
*  INSPECTION FAILURE
   IF(TNKINSF(2).EQ.1)GO TO 8067
ENDIF
       IF(((AGCONT(L).EQ.K).OR.(.NOT.CRADLE)).AND.AGTANK)THEN
        TSURF=TSURF-AGCONFR*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
        TSUB=TSUB-(1-AGCONFR)*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
   SUBSURF=SUBSURF+(1-AGCONFR)*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
               SURF=SURF+AGCONFR*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
            ELSEIF(UGCONT(L).EQ.K)THEN
         TSURF=TSURF-UGCONFR*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
        TSUB=TSUB-(1-UGCONFR)*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
SUBSURF=SUBSURF+(1-UGCONFR)*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
               SURF=SURF+UGCONFR*(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
               ELSEIF(VAULT)  THEN
*      NO CONTAINMENT FAILURE-ALL SURFACE SPILL
               TSURF=TSURF-(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
               SURF=SURF+(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
             ELSE
                TSURF=TSURF-(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
                SURF=SURF+(TKDEFVL(L)+TKLKVOL(L)+RPTKVOL(L))
           ENDIF
   SURF=SURF+TSURF
   TSURF=0
 IF  (SURF.GT.0)  THEN
SURF=SURF+TSURF
TSURF=0
    CALL CLENUP(SURF)
  SURF=0
      PRSURF=0
 ENDIF
CALL VAPZERO(3,1)
IF((TNKDEF(L).EQ.K.OR.TNKLK(L).EQ.K.OR.RUPTNK(L).EQ.K)
+   .AND.YRO.NE.0.AND.IYRNUM.LT.YRO)TANKREP=.TRUE.
          IF(TNKDEF(L).EQ.K)THEN
     IF(IFRAC.NE.1)THEN
       DO 11407 II=FALNUM,1,-1
        IF(FALNUM1(II).EQ.(1030+L))THEN
```

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             FALNUM2(II)=FALNUM2(II)-(1-IFRAC)*TKDEFVL(L)
 FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*TKDEFVL(L)/(60.*TKDEFRT(L)
+ *TANKTIM(L))
         GO TO 11417
       ENDIF
      11407 CONTINUE
      11417 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,3)
         ENDIF
       IF(RUPTNK(L).EQ.K)THEN
    IF(IFRAC.NE.1)THEN
      DO 11408 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(2030+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-IFRAC)*RPTKVOL(L)
 FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*RPTKVOL(L)/(60.*RPTKRT(L)
+  *TANKTIM(L))
         GO TO 11418
       ENDIF
      11408 CONTINUE
      11418 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,2)
       ENDIF
       IF(TNKLK(L).NE.0)THEN
 IF(TNKLK(L).EQ.K)THEN
    IF(IFRAC.NE.1)THEN
      DO 11409 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(3030+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-IFRAC)*TKLKVOL(L)
 FALNUM5(II)=FALNUM5(II)-(1-IFRAC)*TKLKVOL(L)/(60.*TKLKRT(L)
+  *TANKTIM(L))
         GO TO 11419
       ENDIF
      11409 CONTINUE
      11419 CONTINUE
      ENDIF
  ENDIF
 CALL FIX(DLAB,K,YR,L,1)
     ENDIF
          ENDIF
ENDIF
8067 CONTINUE
6010 CONTINUE
ENDIF
*  TANK INTEGRITY TESTING.
IF(TKTSTG)THEN
  IF(TKTEST.EQ.K)THEN
   RATE=0.
   DO 6320 L=1,NPI
     RATE=RPWLRT(L)+GKLKRT(L)+WLDEFRT(L)+GKDEFRT(L)+RATE
      IF(L.LE.NTK)THEN
         RATE=RATE+TKDEFRT(L)+RPTKRT(L)+TKLKRT(L)
      ENDIF
   IF(PITSTG) RATE=RATE+PIDEFRT(L)+PILKRT(L)+RPPIRT(L)
   6320 CONTINUE
     IF(RATE.GE.(TKTSLIM/60.))THEN
```

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         DLAB='TT'
*****                     .05 GALLONS PER HOUR
    DO 63200 L=1,NPI
       TEMPVOL=RPWLVOL (L) +GKLKVOL (L) +WLDEFVL (L) +GKDEFVL (L) +TEMPVOL
    IF (PITSTG)  TEMPVOL=TEMPVOL+PIDEFVL (L) +PILKVOL (L) +RPPIVOL (L)
     IF (PIPCONT (L) .EQ.K) THEN
         TSURF=TSURF-PAGFRAC*TEMPVOL
         SURF=SURF+PAGFRAC*TEMPVOL
         TSUB=TSUB- (1-PAGFRAC) *TEMPVOL
         SUBSURF=SUBSURF+ (1-PAGFRAC) *TEMPVOL
                  ELSE
         TSURF=TSURF-TEMPVOL
         SURF=SURF+TEMPVOL
       ENDIF
    63200 CONTINUE
 DO 117 L=1,NPI
  IF  (GSKLK (L) .NE.O)  CALL FIX (DLAB,K,YR,L,9)
 IF (WLDDEF (L) .EQ.K) CALL FIX (DLAB,K,YR,L,7)
 IF (GSKDEF (L) .EQ.K) CALL FIX (DLAB,K,YR,L,8)
 IF (RUPWLD (L) .EQ.K) CALL FIX (DLAB,K,YR,L,10)
 IF (PITSTG) THEN
       CALL VAPZERO (1,L)
 IF ((PIPLK (L) .EQ.K) .OR. (RUPPIP (L) .EQ.K) .OR. (PIPDEF (L) .EQ.K))
+  CALL FIX (DLAB,K,YR,L,4)
 IF (PIPDEF (L) .EQ.K) CALL FIX (DLAB,K,YR,L,6)
 IF (RUPPIP (L) .EQ.K) CALL FIX (DLAB,K,YR,L,5)
 ENDIF
 117 CONTINUE
 DO 11070 L=1,NTK
  TEMPVOL=TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L)
       IF (AGTANK) THEN
            IF ((AGCONT (L) .EQ.K) .OR. (AGTANK.AND. (.NOT.CRADLE)))  THEN
        TSURF=TSURF-AGCONFR*TEMPVOL
        SURF=SURF+AGCONFR*TEMPVOL
        TSUB=TSUB- (1-AGCONFR) *TEMPVOL
        SUBSURF=SUBSURF+ (1-AGCONFR) *TEMPVOL
       ELSE
        TSURF=TSURF-TEMPVOL
        SURF=SURF+TEMPVOL
       ENDIF
***
    ELSE
*UGTANK
   IF ((UGCONT (L) .EQ.K) .OR.NOSECON.OR. (.NOT.VAULT)) THEN
        TSURF=TSURF-UGCONFR*TEMPVOL
        SURF=SURF+UGCONFR*TEMPVOL
        TSUB=TSUB- (1-UGCONFR) *TEMPVOL
        SUBSURF=SUBSURF+ (1-UGCONFR) *TEMPVOL
   ELSE
        TSURF=TSURF-TEMPVOL
        SURF=SURF+TEMPVOL
   ENDIF
       ENDIF
    CALL VAPZERO (3,1)
 IF ((TNKDEF (L) .EQ.K.OR.TNKLK (L) .EQ.K.OR.RUPTNK (L) .EQ.K)
+   .AND.YRO.NE.O.AND.IYRNUM.LT.YRO) TANKREP=.TRUE.
  IF ((TNKLK (L) .EQ.K) .OR. (TNKDEF (L) .EQ.K) .OR. (RUPTNK (L) .EQ.K))
```

```
50140+ CALL FIX(DLAB,K,YR,L,1)
50145          IF(TNKDEF(L).EQ.K)CALL FIX(DLAB,K,YR,L,3)
50150          IF(RUPTNK(L).EQ.K)CALL FIX(DLAB,K,YR,L,2)
50155       11070 CONTINUE
50160    SURF=SURF+TSURF
50165    TSURF=0
50170  IF (SURF.GT.0) THEN
50175 SURF=SURF+TSURF
50180 TSURF=0
50185     CALL CLENUP(SURF)
50190   SURF=0
50195       PRSURF=0
50200  ENDIF
50205   ENDIF
50210    ENDIF
50215  ENDIF
50220  IF((PITSTG.AND.(.NOT.TKTSTG)).OR.PIPMON) THEN
50225*   PIPE INTEGRITY TESTING OR CONTINUOUS PIPE MONITORING
50230     IF(PITEST.EQ.K.OR.PIPMON) THEN
50235        DO 41777 L=1,NPI
50240  RATE=PIDEFRT(L)+PILKRT(L)+RPPIRT(L)
50245       41777 CONTINUE
50250   IF(PIPMON)THEN
50255     DLAB='PM'
50260     PMONRT=PIMNLIM/60.
50265   ELSE
50270     PMONRT=PITSLIM/60.
50275     DLAB='PT'
50280    ENDIF
50285        IF(RATE.GE.PMONRT)THEN
50290*       .05 GAL PER HR
50295    DO 147 L=1,NPI
50300          TEMPVOL=PIDEFVL(L)+RPPIVOL(L)+
50305+                PILKVOL(L)
50310     IF(PIPCONT(L).EQ.K)THEN
50315        TSURF=TSURF-PAGFRAC*TEMPVOL
50320        SURF=SURF+PAGFRAC*TEMPVOL
50325        TSUB=TSUB-(1-PAGFRAC)*TEMPVOL
50330        SUBSURF=SUBSURF+(1-PAGFRAC)*TEMPVOL
50335                ELSE
50340        TSURF=TSURF-TEMPVOL
50345        SURF=SURF+TEMPVOL
50350      ENDIF
50355      CALL VAPZERO(1,L)
50360 IF(PIPDEF(L).EQ.K)CALL FIX(DLAB,K,YR,L,6)
50365 IF(RUPPIP(L).EQ.K)CALL FIX(DLAB,K,YR,L,5)
50370    IF (PIPLK(L).NE.0) CALL FIX(DLAB,K,YR,L,4)
50375    147 CONTINUE
50380 ENDIF
50385    SURF=SURF+TSURF
50390    TSURF=0
50395  IF (SURF.GT.0) THEN
50400 SURF=SURF+TSURF
50405 TSURF=0
50410     CALL CLENUP(SURF)
50415   SURF=0
50420       PRSURF=0
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```
50425  ENDIF
50430  ENDIF
50435  ENDIF
50440 IF (ULTRTST) THEN
50445*   ULTRASONIC TESTING
50450   IF (ULTEST.EQ.K) THEN
50455    DO 11071 L=1,NTK
50460    TKTHICK=MIN (TANKI (L) ,TANKE (L))
50465      IF (TKTHICK.LT..015625) THEN
50470         DLAB='US'
50475*        **** 1/64 INCH ***
50480         TEMPVOL=TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L)
50485      IF (AGTANK) THEN
50490          IF ((AGCONT (L) .EQ.K) .OR. (AGTANK.AND. (.NOT.CRADLE))) THEN
50495        TSURF=TSURF-AGCONFR*TEMPVOL
50500        SURF=SURF+AGCONFR*TEMPVOL
50505        TSUB=TSUB- (1-AGCONFR) *TEMPVOL
50510        SUBSURF=SUBSURF+ (1-AGCONFR) *TEMPVOL
50515               ELSE
50520        TSURF=TSURF-TEMPVOL
50525        SURF=SURF+TEMPVOL
50530            ENDIF
50535          ELSE
50540*       *UGTANK.OR.IGTANK
50545     IF ((UGCONT (L) .EQ.K) .OR.NOSECON.OR. (.NOT.VAULT)) THEN
50550        TSURF=TSURF-UGCONFR*TEMPVOL
50555        SURF=SURF+UGCONFR*TEMPVOL
50560        TSUB=TSUB- (1-UGCONFR) *TEMPVOL
50565        SUBSURF=SUBSURF+ (1-UGCONFR) *TEMPVOL
50570               ELSE
50575        TSURF=TSURF-TEMPVOL
50580        SURF=SURF+TEMPVOL
50585             ENDIF
50590         ENDIF
50595        CALL VAPZERO (3,1)
50600 IF ((TNKDEF (L) .EQ.K.OR.TNKLK (L) .EQ.K.OR.RUPTNK (L) .EQ.K)
50605+   .AND.YRO.NE.O.AND.IYRNUM.LT.YRO) TANKREP=.TRUE.
50610          IF (TNKDEF (L) .EQ.K) CALL FIX (DLAB,K,YR,L,3)
50615          IF (RUPTNK (L) .EQ.K) CALL FIX (DLAB,K,YR,L,2)
50620       IF  (TNKLK (L) .NE.O)  CALL FIX (DLAB,K,YR,L,1)
50625    SURF=SURF+TSURF
50630    TSURF=0
50635  IF  (SURF.GT.0)  THEN
50640 SURF=SURF+TSURF
50645 TSURF=0
50650     CALL CLENUP (SURF)
50655   SURF=0
50660       PRSURF=0
50665  ENDIF
50670     ENDIF
50675    11071 CONTINUE
50680  ENDIF
50685 ENDIF
50690  IF  (AGTANK)  THEN
50695 TREMVL= (1-AGCONFR) * (TKVOL (1) -PRTKVOL (1) +WLVOL (1) -PRWLVOL (1) +WLVOL
50700+(2) -WLVOL (2) +GKVOL (1) -PRGKVOL (1) +GKVOL (2) -PRGKVOL (2)) /264.2
50705+  + (1-AGFRAC) *CATVOL/264.2
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50710 ELSE
50715 TREMVL=(1-UGCONFR)*(TKVOL(1)-PRTKVOL(1)+WLVOL(1)-PRWLVOL(1)+WLVOL
50720+(2)-WLVOL(2)+GKVOL(1)-PRGKVOL(1)+GKVOL(2)-PRGKVOL(2))/264.2
50725+        +CATVOL/264.2
50730 ENDIF
50735 TTREMVL=TTREMVL+TREMVL
50740 PREMDT=PREMDT/1440.
50745 PREMRT=PREMRT/15850.
50750 PREMVL=((1-PAGFRAC)*(PIVOL(1)-PRPIVOL(1)+PIVOL(2)-PRPIVOL(2))
50755+  +(1-AGCONFR)*(PMVOL(1)-PRPMVOL(1)+PMVOL(2)-PRPMVOL(2)))/264.2
50760 TPREMVL=TPREMVL+PREMVL
50765 CALL PENET(1,PREMRT,PREMVL,PREMDT)
50770 PREMDT=PREMDT*1440.
50775 PREMRT=PREMRT*15850.
50780 WKPPNDR=PMOPEN/4.
50785 PPNDPTH=PPNDPTH+PMOPEN
50790 WKDROP=0
50795 IF(.NOT.((YR.EQ.1).AND.(K.EQ.1)))THEN
50800     IF((TPNDPTH.GT.0).AND.(GDROP.EQ.0)) THEN
50805       WKDROP=MCWHORT/4.
50810          GDROP=TPNDPTH+MCWHORT
50815     ELSEIF (TPNDPTH.GT.0) THEN
50820          WKDROP=MCWHORT/4.
50825          GDROP=GDROP+MCWHORT
50830    ELSE
50835      IF(TREMRT.EQ.0) THEN
50840      GO TO 420
50845     ENDIF
50850      ENDIF
50855  ENDIF
50860 IF(.NOT.(RUPWLD(1).EQ.0.AND.RUPWLD(2).EQ.0.AND.WLDDEF(1).EQ.0
50865+.AND.WLDDEF(2).EQ.0.AND.GSKDEF(1).EQ.0.AND.GSKDEF(2).EQ.0.AND.
50870+GSKLK(1).EQ.0.AND.GSKLK(2).EQ.0.AND.TNKDEF(1).EQ.0.AND.
50875+TNKLK(1).EQ.0.AND.RUPTNK(1).EQ.0)) THEN
50880     TREMDT=TREMDT/1440.
50885     TREMRT=TREMRT/15850.
50890     CALL PENET(3,TREMRT,TREMVL,TREMDT)
50895        TREMRT=TREMRT*15850.
50900        TREMDT=TREMDT*1440.
50905        WKPNDR=TMOPEN/4.
50910 TPNDPTH=TPNDPTH+TMOPEN
50915 IF  (TPNDPTH.GT.GDROP) THEN
50920        WKDROP=WKPNDR
50925      GDROP=TPNDPTH
50930 ENDIF
50935 ENDIF
50940 420 CONTINUE
50945* U-TUBE AND POLLULERT MONITORING
50950 IF(MONMETH(6))THEN
50955    IF(PPNDPTH.GT.GDROP)THEN
50960       WKDROP=WKPPNDR
50965       GDROP=PPNDPTH
50970       WKPPNDR=0
50975    ENDIF
50980    ENDIF
50985 IF(MONMETH(4).OR.MONMETH(6))THEN
50990   IF(MONMETH(4))DLAB='UT'
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  IF(MONMETH(6))DLAB='PO'
IF  (LYSTEST.EQ.K.OR.MONMETH(6))  THEN
   LYSIM(2)=FNB(LYSIM(1))
   IF(LYSIM(2).EQ.0)THEN
      UFRAC=1.0
      IF(LTSTFRQ.EQ.4)THEN
         GDROP=GDROP-(WKDROP*4)
         UFRAC=0.
         DO 7037 LL=1,4
            GDROP=GDROP+WKDROP
            UFRAC=UFRAC+0.25
            IF(GDROP.GE.LYSDPTH)THEN
               GO TO 7038
            ENDIF
         7037 CONTINUE
         7038 CONTINUE
      ENDIF
      IF(MONMETH(6))THEN
         GDROP=GDROP-(WKDROP*4)
         UFRAC=0.
         DO 70377 LL=1,30
            GDROP=GDROP+(WKDROP*4/30.)
            UFRAC=UFRAC+(1./30.)
            IF(GDROP.GE.LYSDPTH)THEN
               GO TO 70388
            ENDIF
         70377 CONTINUE
         70388 CONTINUE
      ENDIF
      IF(GDROP.GE.LYSDPTH)THEN
         WKDROP=0.
         IF(MONMETH(6))THEN
       DO 1611 L=1,NPI
   IF((PIPDEF(L).EQ.K).OR.(RUPPIP(L).EQ.K).OR.(PIPLK(L).EQ.K)
       )THEN
  IF(PIPCONT(L).EQ.K)THEN
    TSURF=TSURF-PAGFRAC*(PILKVOL(L)+RPPIVOL(L)+
      PIDEFVL(L))

    SURF=SURF+PAGFRAC*UFRAC*(PILKVOL(L)+RPPIVOL(L)+
      PIDEFVL(L))

    TSUB=TSUB-(1-PAGFRAC)*(PILKVOL(L)+RPPIVOL(L)
    +PIDEFVL(L))

    SUBSURF=SUBSURF+(1-PAGFRAC)*UFRAC*(PILKVOL(L)+RPPIVOL(L)+
      PIDEFVL(L))

   ELSE
     TSURF=TSURF-(PILKVOL(L)+RPPIVOL(L)+
       PIDEFVL(L))

     SURF=SURF+UFRAC*(PILKVOL(L)+RPPIVOL(L)+
      PIDEFVL(L))

   ENDIF
IF((PIPLK(L).EQ.K).OR.(PIPDEF(L).EQ.K).OR.(RUPPIP(L).EQ.K))THEN
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     IF(UFRAC.NE.1)THEN
       DO 11302 II=FALNUM,1,-1
         IF(FALNUM1(II).EQ.(3010+L))THEN
               FALNUM2(II)=FALNUM2(II)-(1-UFRAC)*PILKVOL(L)
           IF(FALNUM5(II).GT.720)THEN
               FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*720
           ELSEIF(L.NE.1)THEN
FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*PILKVOL(L)/(PILKRT(L)
   *DISCFR(L)*DISCTIM(L)/24.)
           ELSE
 FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*PILKVOL(L)/(PILKRT(L)
          *FILLFR(L)*FILLTIM(L)/24.)
           ENDIF
           GO TO 11312
         ENDIF
         11302 CONTINUE
         11312 CONTINUE
       ENDIF
  CALL FIX(DLAB,K,YR,L,4)
ENDIF
IF(PIPDEF(L).EQ.K)THEN
     IF(UFRAC.NE.1)THEN
       DO 11300 II=FALNUM,1,-1
         IF(FALNUM1(II).EQ.(1010+L))THEN
               FALNUM2(II)=FALNUM2(II)-(1-UFRAC)*PIDEFVL(L)
           IF(FALNUM5(II).GT.720)THEN
               FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*720
           ELSEIF(L.NE.1)THEN
FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*PIDEFVL(L)/(PIDEFRT(L)
   *DISCFR(L)*DISCTIM(L)/24.)
           ELSE
 FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*PIDEFVL(L)/(PIDEFRT(L)
          *FILLFR(L)*FILLTIM(L)/24.)
           ENDIF
           GO TO 11310
         ENDIF
         11300 CONTINUE
         11310 CONTINUE
       ENDIF
  CALL FIX(DLAB,K,YR,L,6)
ENDIF
IF(RUPPIP(L).EQ.K)THEN
     IF(UFRAC.NE.1)THEN
       DO 11301 II=FALNUM,1,-1
         IF(FALNUM1(II/.EQ.(2010+L))THEN
               FALNUM2(II)=FALNUM2(II)-(1-UFRAC)*RPPIVOL(L)
           IF(FALNUM5(II).GT.720)THEN
               FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*720
           ELSEIF(L.NE.1)THEN
FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*RPPIVOL(L)/(RPPIRT(L)
   *DISCFR(L)*DISCTIM(L)/24.)
           ELSE
 FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*RPPIVOL(L)/(RPPIRT(L)
          *FILLFR(L)*FILLTIM(L)/24.)
           ENDIF
           GO TO 11311
         ENDIF
       11301 CONTINUE
       11311 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,5)
ENDIF
ENDIF
1611 CONTINUE
ENDIF
DO 317 L=1,NPI
   TEMPVOL=WLDEFVL(L)+GKDEFVL(L)+
+         RPWLVOL(L)+GKLKVOL(L)
    IF(((UGCONT(L-1+1/L-L/5).EQ.K).AND.(UGTANK
+.OR.IGTANK)).OR.NOSECON)THEN
       TSURF=TSURF-UGCONFR*TEMPVOL
       SURF=SURF+UGCONFR*TEMPVOL*UFRAC
       TSUB=TSUB-(1-UGCONFR)*TEMPVOL
       SUBSURF=SUBSURF+(1-UGCONFR)*TEMPVOL*UFRAC
 ELSEIF(AGTANK.AND.((AGCONT(L-1+1/L-L/5).EQ.K)
+.OR.(.NOT.CRADLE)))THEN
       TSURF=TSURF-AGCONFR*TEMPVOL
       SURF=SURF+AGCONFR*TEMPVOL*UFRAC
       TSUB=TSUB-(1-AGCONFR)*TEMPVOL
       SUBSURF=SUBSURF+(1-AGCONFR)*TEMPVOL*UFRAC
               ELSE
       TSURF=TSURF-TEMPVOL
       SURF=SURF+TEMPVOL*UFRAC
     ENDIF
IF(GSKLK(L).NE.0)THEN
 IF(GSKLK(L).EQ.K)THEN
    IF(UFRAC.NE.1)THEN
      DO 11303 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(3050+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-UFRAC)*GKLKVOL(L)
         IF(FALNUM5(II).GT.720)THEN
             FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*720
         ELSEIF(L.NE.1)THEN
FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*GKLKVOL(L)/(TANKTIM(
+L-1+1/L-L/5)*60.*GKLKRT(L))
         ELSE
 FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*GKLKVOL(L)/(GKLKRT(L)
+       *FILLFR(L)*FILLTIM(L)/24.)
         ENDIF
         GO TO 11313
       ENDIF
      11303 CONTINUE
      11313 CONTINUE
      ENDIF
  ENDIF
 CALL FIX(DLAB,K,YR,L,9)
ENDIF
IF(WLDDEF(L).EQ.K)THEN
    IF(UFRAC.NE.1)THEN
      DO 11304 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(1040+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-UFRAC)*WLDEFVL(L)
         IF(FALNUM5(II).GT.720)THEN
             FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*720
         ELSEIF(L.NE.1)THEN
FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*WLDEFVL(L)/(TANKTIM(
+L-1+1/L-L/5)*60.*WLDEFRT(L))
         ELSE
 FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*WLDEFVL(L)/(WLDEFRT(L)
+        *FILLFR(L)*FILLTIM(L)/24.)
         ENDIF
         GO TO 11314
       ENDIF
      11304 CONTINUE
      11314 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,7)
ENDIF
IF(RUPWLD(L).EQ.K)THEN
    IF(UFRAC.NE.1)THEN
      DO 11305 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(2040+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-UFRAC)*RPWLVOL(L)
         IF(FALNUM5(II).GT.720)THEN
             FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*720
         ELSEIF(L.NE.1)THEN
FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*RPWLVOL(L)/(TANKTIM(
+L-1+1/L-L/5)*60.*RPWLRT(L))
         ELSE
 FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*RPWLVOL(L)/(RPWLRT(L)
+        *FILLFR(L)*FILLTIM(L)/24.)
         ENDIF
         GO TO 11315
       ENDIF
      11305 CONTINUE
      11315 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,10)
ENDIF
IF(GSKDEF(L).EQ.K)THEN
    IF(UFRAC.NE.1)THEN
      DO 11306 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.(1050+L))THEN
             FALNUM2(II)=FALNUM2(II)-(1-UFRAC)*GKDEFVL(L)
         IF(FALNUM5(II).GT.720)THEN
             FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*720
         ELSEIF(L.NE.1)THEN
FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*GKDEFVL(L)/(TANKTIM(
+L-1+1/L-L/5)*60.*GKDEFRT(L))
         ELSE
 FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*GKDEFVL(L)/(GKDEFRT(L)
+        *FILLFR(L)*FILLTIM(L)/24.)
         ENDIF
         GO TO 11316
       ENDIF
      11306 CONTINUE
      11316 CONTINUE
      ENDIF
 CALL FIX(DLAB,K,YR,L,8)
ENDIF
317 CONTINUE
```

```
DO 3017 L=1,NTK
  TEMPVOL=TKDEFVL (L) +TKLKVOL (L) +RPTKVOL (L)
     IF (AGTANK) THEN
         IF ((AGCONT (L) .EQ.K) .OR. (AGTANK.AND. (.NOT.CRADLE))) THEN
       TSURF=TSURF-AGCONFR*TEMPVOL
       SURF=SURF+AGCONFR*TEMPVOL*UFRAC
       TSUB=TSUB- (1-AGCONFR) *TEMPVOL
       SUBSURF=SUBSURF+ (1-AGCONFR) *TEMPVOL*UFRAC
      ELSE
       TSURF=TSURF-TEMPVOL
       SURF=SURF+TEMPVOL*UFRAC
      ENDIF
    ELSE
*UGTANK  OR IGTANK
  IF ((UGCONT (L) .EQ.K) .OR.NOSECON.OR. (.NOT.VAULT)) THEN
       TSURF=TSURF-UGCONFR*TEMPVOL
       SURF=SURF+UGCONFR*TEMPVOL*UFRAC
       TSUB=TSUB- (1-UGCONFR) *TEMPVOL
       SUBSURF=SUBSURF+ (1-UGCONFR) *TEMPVOL*UFRAC
  ELSE
       TSURF=TSURF-TEMPVOL
       SURF=SURF+TEMPVOL*UFRAC
  ENDIF
      ENDIF
    CALL VAPZERO (3,1)
IF ((TNKDEF (L) .EQ.K.OR.TNKLK (L) .EQ.K.OR.RUPTNK (L) .EQ.K)
+   .AND.YRO.NE.0.AND.IYRNUM.LT.YRO) TANKREP=.TRUE.
IF ((TNKLK (L) .EQ.K) .OR. (TNKDEF (L) .EQ.K) .OR. (RUPTNK (L) .EQ.K)) THEN
    IF (UFRAC.NE.1) THEN
      DO 11309 II=FALNUM,1,-1
       IF (FALNUM1 (II) .EQ.3030+L) THEN
             FALNUM2 (II) =FALNUM2 (II) - (1-UFRAC) *TKLKVOL (L)
         IF (FALNUM5 (II) .GT.720) THEN
             FALNUM5 (II) =FALNUM5 (II) - (1-UFRAC) *720
         ELSE
FALNUM5 (II) =FALNUM5 (II) - (1-UFRAC) *TKLKVOL (L) / (60.*TANKTIM (L)
+*TKLKRT (L))
         ENDIF
         GO TO 11319
       ENDIF
      11309 CONTINUE
      11319 CONTINUE
      ENDIF
 CALL FIX (DLAB,K,YR,L,1)
     ENDIF
         IF (TNKDEF (L) .EQ.K) THEN
    IF (UFRAC.NE.1) THEN
      DO 11307 II=FALNUM,1,-1
       IF (FALNUM1 (II) .EQ.1030+L) THEN
             FALNUM2 (II) =FALNUM2 (II) - (1-UFRAC) *TKDEFVL (L)
         IF (FALNUM5 (II) .GT.720) THEN
             FALNUM5 (II) =FALNUM5 (II) - (1-UFRAC) *720
         ELSE
FALNUM5 (II) =FALNUM5 (II) - (1-UFRAC) *TKDEFVL (L) / (60.*TANKTIM (L)
+*TKDEFRT (L))
         ENDIF
         GO TO 11317
      ENDIF
     11307 CONTINUE
     11317 CONTINUE
     ENDIF
CALL FIX(DLAB,K,YR,L,3)
         ENDIF
         IF(RUPTNK(L).EQ.K)THEN
    IF(UFRAC.NE.1)THEN
      DO 11308 II=FALNUM,1,-1
       IF(FALNUM1(II).EQ.2030+L)THEN
             FALNUM2(II)=FALNUM2(II)-(1-UFRAC)*RPTKVOL(L)
         IF(FALNUM5(I!).GT.720)THEN
             FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*720
         ELSE
FALNUM5(II)=FALNUM5(II)-(1-UFRAC)*RPTKVOL(L)/(60.*TANKTIM(L)
+*RPTKRT(L))
         ENDIF
         GO TO 11318
       ENDIF
      11308 CONTINUE
      11318 CONTINUE
      ENDIF
CALL FIX(DLAB,K,YR,L,2)
       ENDIF
3017 CONTINUE
   SURF=SURF+TSURF
   TSURF=0
 IF (SURF.GT.0) THEN
SURF=SURF+TSURF
TSURF=0
    CALL CLENUP(SURF)
  SURF=0
      PRSURF=0
 ENDIF
ENDIF
  ELSE
*      SET PROBABILITY OF LYSIMETER FAILURE=1.0
*     LYSIM(1)=1.0
  ENDIF
   ENDIF
ENDIF
   QTR=(YR-1)*4+K/3
PICFAIL=.FALSE.
TKCFAIL=.FALSE.
DO 82469 L=1,NPI
    IF(PIPCONT(L).EQ.K)PICFAIL=.TRUE.
    IF(L.LE.NTK)THEN
IF(((UGCONT(L).EQ.K).AND.(UGTANK.OR.IGTANK)).OR.((AGCONT(L).EQ.K)
+    .AND.AGTANK))TKCFAIL=.TRUE.
    ENDIF
82469 CONTINUE
IF((TKCFAIL.AND.(UGTANK.OR.IGTANK)).OR.PICFAIL)THEN
    TSUB=TSUB+TSURF
    IF(TKCFAIL.AND.(UGTANK.OR.IGTANK))THEN
    TREMVL=TREMVL+TSURF
    ELSE
    PREMVL=PREMVL+TSURF
```

```
52705    ENDIF
52710    TSURF=0
52715 ENDIF
52720 IF(TKCFAIL.AND.AGTANK)THEN
52725    TSUB=TSUB+TSURF
52730    TREMVL=TREMVL+TSURF
52735    TSURF=0
52740 ENDIF
52745 IF(.NOT.((TKCFAIL.AND.(UGTANK.OR.IGTANK)).OR.
52750+(TKCFAIL.AND.AGTANK.AND.CRADLE).OR.(TKCFAIL
52755+.AND.AGTANK.AND.(.NOT.CRADLE))).AND.(CATASTR(K).NE.K))
52760+TREMREP=.FALSE.
52765 CATASTR(K)=0
52770 IF(.NOT.PICFAIL)PREMREP=.FALSE.
52775 IF(TREMREP.OR.PREMREP)FLREMED=.FALSE.
52780 IF(QTR.EQ.0)QTR=1
52785 IF  (TREMREP)  THEN
52790    TPNDPTH=TPNDPTH-TMOPEN
52795    TREMDT=TREMDT+2.
52800    CALL PENET(3,TREMRT,TREMVL,TREMDT)
52805       TREMRT=TREMRT*15850.
52810       TREMDT=TREMDT*1440.
52815    TPNDPTH=TPNDPTH+TMOPEN
52820     IF((TPNDPTH+TXDEPTH(1)).LT.(PPNDPTH+PXDEPTH(1)))  THEN
52825        TPNDPTH=PPNDPTH+PXDEPTH(1)-TXDEPTH(1)
52830      ENDIF
52835       POOF=FLASHTM
52840       PREMREP=.FALSE.
52845     TRVOL=TRVOL+(TTREMVL*264.2)+(TPREMVL*264.2)
52850*   VOL1=0.
52855*    SUBSURF=0
52860*      PRSUB=0
52865*      TSUB=0
52870*      TPRSUB=0
52875       TMOPEN=0
52880*       QUARSUB=0
52885*     TPREMVL=0.
52890       TPNDPTH=0
52895       PPNDPTH=0
52900        GDROP=0
52905*    TTREMVL=0.
52910*      MREL=0.
52915 ELSEIF  (PREMREP)  THEN
52920   PPNDPTH=PPNDPTH-PMOPEN
52925   PREMDT=PREMDT+2.
52930   CALL PENET(1,PREMRT,PREMVL,PREMDT)
52935 PREMDT=PREMDT*1440.
52940 PREMRT=PREMRT*15850.
52945   PPNDPTH=PPNDPTH+PMOPEN
52950     POOF=FLASHTM
52955     TRVOL=TRVOL+(TPREMVL*264.2)
52960     TPREMVL=0.
52965*      VOL1=0.
52970*      SUBSURF=0
52975*       QUARSUB=0
52980*      TSUB=0
52985*      PRSUB=0
```

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52990*       TPRSUB=0-
52995        TMOPEN=0
53000        PPNDPTH=0
53005*       MREL=0.
53010 ELSE
53015 ENDIF
53020 IF (CONCRT) THEN
53025    DO 91743 L=1,NTK
53030    IF ((((AGCONT (L) .EQ.K) .OR. (.NOT.CRADLE)) .AND.AGTANK) .OR.
53035+       ((UGCONT (L) .EQ.K) .AND. (IGTANK.OR.UGTANK))) THEN
53040        MREL=MREL+PERMREL (L)
53045    ENDIF
53050    91743 CONTINUE
53055 ENDIF
53060 IF (FALNUM.NE.0) THEN
53065   DO 692 II=1,FALNUM
53070       IF ((FALNUM3 (II) .EQ. ((YR-1) *12+K)) .AND. (FALNUM4 (II) .EQ.0)) THEN
53075         IITYP=INT (MOD (FALNUM1 (II) , 1000) /10)
53080         IF ((IITYP.EQ.3) .OR.
53085+(IITYP.EQ.7) .OR. (IITYP.EQ.8) .OR. (IITYP.EQ.9) .OR. (IITYP
53090+.EQ.10)) THEN
53095  IF ((AGTANK.AND. ((AGCONT (MOD (FALNUM1 (II) , 10)) .EQ.K) .OR.
53100+(.NOT.CRADLE))) .AND. (IITYP.EQ.3)) FALNUM4 (II)=1
53105  IF ((AGTANK.AND. ((AGCONT (MOD (FALNUM1 (II) , 10)) .EQ.K)
53110+)) .AND. (.NOT. (IITYP.EQ.3))) FALNUM4 (II)=1
53115 IF (IGTANK.AND. (IITYP.EQ.3) .AND. (UGCONT (MOD (
53120+FALNUM1 (II) , 10)) .EQ.K)) FALNUM4 (II)=1
53125 IF (IGTANK.AND..NOT. (IITYP.EQ.3) .AND. (AGCONT (MOD (
53130+FALNUM1 (II) , 10)) .EQ.K)) FALNUM4 (II)=1
53135     IF (UGTANK.AND. (UGCONT (MOD (FALNUM1 (II) , 10)) .EQ.K)) FALNUM4 (II)=1
53140          ELSEIF ((IITYP.EQ.5) .OR. (IITYP.EQ.4)) THEN
53145               L=MOD (FALNUM1 (II) , 10)
53150  IF (AGTANK.AND. ((PIPCONT (L) .EQ.K)
53155+)) FALNUM4 (II)=1
53160 IF (IGTANK.AND. (PIPCONT (
53165+L) .EQ.K)) FALNUM4 (II)=1
53170 IF (UGTANK.AND. (UGCONT (L-1+1/L-L/5) .EQ.K))
53175+FALNUM4 (II)=1
53180          ELSEIF (IITYP.EQ.1) THEN
53185             IF (PIPCONT (MOD (FALNUM1 (II) , 10)) .EQ.K) FALNUM4 (II)=1
53190          ELSEIF ((IITYP.EQ.2) .OR. (IITYP.EQ.11)) THEN
53195           L=MOD (FALNUM1 (II) , 10)
53200  IF (AGPUMP.AND. (PIPCONT (L) .EQ.K)
53205+) FALNUM4 (II)=1
53210          ELSE
53215             FALNUM4 (II)=1
53220          ENDIF
53225      ENDIF
53230   692 CONTINUE
53235 ENDIF
53240*   SAMPLE TO SEE IF SECONDARY CONTAINMENT FAILURE CONTINUES
53245 DO 69986 L=1,NPI
53250 IF (L.LE.NTK) THEN
53255 IF ((AGCONT (L) .EQ.K) .AND. (CONCPAD.OR.ASPHPAD)) THEN
53260   SECINSP (2)=FNB (SECINSP (1))
53265   IF (SECINSP (2) .EQ.1.)  THEN
53270      AG2DET=.TRUE.
```

```
   ENDIF
   IF (AG2DET) THEN
      AGCONT (L) =0
               NAGCONT (L) =0
          CALL REPLAC (7,1)
    ELSE
      IF (K.EQ.12) THEN
          AGCONT (L) =1
            NAGCONT (L) =1
       ELSE
         AGCONT (L) =K+1
         NAGCONT (L) =0
      ENDIF
   ENDIF
ENDIF
IF ((UGCONT (L) .EQ.K) .AND.VAULT) THEN
  SECINSP (2) =FNB (SECINSP (1))
  IF (SECINSP (2) .EQ.1.) THEN
    UG2DET=.TRUE.
   ENDIF
  IF (UG2DET) THEN
     UGCONT (L) =0
              NUGCONT (L) =0
      IF (LVAULT) LINETIM (L) =FNN (9.,3.) +IYRNUM
         CALL REPLAC (7,1)
    ELSE
     IF (K.EQ.12) THEN
       NUGCONT (L) =1
       UGCONT (L) =1
      ELSE
       UGCONT (L) =K+1
       NUGCONT (L) =0
     ENDIF
   ENDIF
ENDIF
ENDIF
IF ((PIPCONT (L) .EQ.K) .AND.PIPSEC) THEN
  SECINSP (2) =FNB (SECINSP (1))
  IF (SECINSP (2) .EQ.1.) THEN
      PI2DET=.TRUE.
   ENDIF
  IF (PI2DET) THEN
     PIPCONT (L) =0
     NPICONT (L) =0
   IF (PLINER.AND. (COPAD.OR.ASPAD)) PLINTIM (L) =FNN (9.,3.)
   +IYRNUM
   CALL REPLAC (6,1)
    ELSE
     IF (K.EQ.12) THEN
       NPICONT (L) =1
       PIPCONT (L) =1
      ELSE
       PIPCONT (L) =K+1
       NPICONT (L) =0
     ENDIF
  ENDIF
ENDIF
```

```
IF (L.LE.NTK) THEN
IF (NOSECON) THEN
   IF (K.EQ.12) THEN
      AGCONT (L) =1
      NAGCONT (L) =1
      UGCONT (L) =1
      NUGCONT (L) =1
     ELSE
      AGCONT (L) =K+1
      UGCONT (L) =K+1
      NAGCONT (L) =0
      NUGCONT (L) =0
   ENDIF
ENDIF
IF (RETROFT) THEN
   IF (K.EQ.12) THEN
      UGCONT (L) =1
      NUGCONT (L) =1
     ELSE
      UGCONT (L) =K+1
      NUGCONT (L) =0
   ENDIF
ENDIF
ENDIF
IF (.NOT.PIPSEC) THEN
   IF (K.EQ.12) THEN
      PIPCONT (L) =1
      NPICONT (L) =1
     ELSE
      PIPCONT (L) =K+1
      NPICONT (L) =0
   ENDIF
ENDIF
69986 CONTINUE
DO 73 L=1,NPI
IF (PIPDEF (L) .EQ.12) THEN
   NPIPDEF (L) =1
   PIPDEF (L) =0
  ELSEIF (PIPDEF (L) .EQ.K) THEN
   PIPDEF (L) =PIPDEF (L) +1
   NPIPDEF (L) =0
  ELSE
    NPIPDEF (L) =0
ENDIF
IF (WLDDEF (L) .EQ.12) THEN
   NWLDDEF (L) =1
   WLDDEF (L) =0
  ELSEIF (WLDDEF (L) .EQ.K) THEN
   WLDDEF (L) =WLDDEF (L) +1
   NWLDDEF (L) =0
  ELSE
    NWLDDEF (L) =0
ENDIF
IF (GSKDEF (L) .EQ.12) THEN
   NGSKDEF (L) =1
   GSKDEF (L) =0
  ELSEIF (GSKDEF (L) .EQ.K) THEN
```

```
   GSKDEF (L) =GSKDEF (L) +1
   NGSKDEF (L) =0
  ELSE
     NGSKDEF (L) =0
ENDIF
IF (PIPLK (L) .EQ.12) THEN
   NPIPLK (L) =1
   PIPLK (L) =0
  ELSEIF (PIPLK (L) .EQ.K) THEN
   PIPLK (L) =PIPLK (L) +1
   NPIPLK (L) =0
  ELSE
      NPIPLK (L) =0
ENDIF
IF (GSKLK (L) .EQ.12) THEN
   NGSKLK (L) =1
   GSKLK (L) =0
  ELSEIF (GSKLK (L) .EQ.K) THEN
   GSKLK (L) =GSKLK (L) +1
   NGSKLK (L) =0
  ELSE
      NGSKLK (L) =0
ENDIF
IF (RUPPIP (L) .EQ.12) THEN
   NRUPPIP (L) =1
   RUPPIP (L) =0
  ELSEIF (RUPPIP (L) .EQ.K) THEN
   RUPPIP (L) =RUPPIP (L) +1
   NRUPPIP (L) =0
  ELSE
       NRUPPIP (L) =0
ENDIF
IF (PMPLK (L) .EQ.12) THEN
   NPMPLK (L) =1
   PMPLK (L) =0
  ELSEIF (PMPLK (L) .EQ.K) THEN
   PMPLK (L) =PMPLK (L) +1
   NPMPLK (L) =0
  ELSE
      NPMPLK (L) =0
ENDIF
IF (RUPWLD (L) .EQ.12) THEN
   NRUPWLD (L) =1
   RUPWLD (L) =0
  ELSEIF (RUPWLD (L) .EQ.K) THEN
   RUPWLD (L) =RUPWLD (L) +1
   NRUPWLD (L) =0
  ELSE
      NRUPWLD (L) =0
ENDIF
73 CONTINUE
DO 7300 L=1,NTK
IF (TNKLK (L) .EQ.12) THEN
   NTNKLK (L) =1
   TNKLK (L) =0
  ELSEIF (TNKLK (L) .EQ.K) THEN
   TNKLK (L) =TNKLK (L) +1
```

```
     NTNKLK(L)=0
    ELSE
       NTNKLK(L)=0
 ENDIF
 IF(TNKDEF(L).EQ.12)THEN
     NTNKDEF(L)=1
     TNKDEF(L)=0
    ELSEIF(TNKDEF(L).EQ.K)THEN
     TNKDEF(L)=TNKDEF(L)+1
     NTNKDEF(L)=0
    ELSE
       NTNKDEF(L)=0
 ENDIF
 IF(RUPTNK(L).EQ.12)THEN
     NRUPTNK(L)=1
     RUPTNK(L)=0
    ELSEIF(RUPTNK(L).EQ.K)THEN
     RUPTNK(L)=RUPTNK(L)+1
     NRUPTNK(L)=0
    ELSE
       NRUPTNK(L)=0
 ENDIF
 7300 CONTINUE
 IF(SURF.LE.0)PRSURF=0
 IF(TSURF.LE.0)TPRSURF=0
 MREL=(TSUB-TPRSUB)+(TSURF-TPRSURF)+MREL+(SURF-PRSURF)+(SUBSURF-
+PRSUB)
 AGSPILL=0
 AGLEAK=0
 AGRUPT=0
 UGRUPT=0
 UGLEAK=0
 IF(TANKREP)GO TO 290
 50 CONTINUE
 GO TO 291
 290 CONTINUE
 IF(RETROFT)CALL RETRO
 291 CONTINUE
 TVOLUME(IYRNUM)=TVOLUME(IYRNUM)+MREL
 IF(YR.EQ.1)  THEN
  VOL1=0
 ENDIF
 VOL1=VOL1+MREL
 RETURN
 END
 SUBROUTINE RATEDET(RATE,TMIN,TIME1,TIME2,DETECT,DETTIME)
*   'RATEDET'  ESTIMATES THE TIME OF DETECTION BASED ON
*   THE SIZE OF THE RELEASE RATE.  THE COMPONENT MUST
*   BE ABLE TO BE VISUALLY INSPECTED IN A CASUAL MANNER.

 REAL RATE,TIME1,TIME2,DETTIME,TMIN
 LOGICAL DETECT

 DETECT=.FALSE.
 IF(RATE.GE..375)THEN
     DETTIME=FNU(TMIN,TIME1)
     DETECT=.TRUE.
```

```
54415   ELSEIF(RATE.GE..002)THEN
54420    DET=FNB(0.5)
54425    IF(DET.EQ.1)THEN
54430       DETTIME=FNU(TMIN,TIME2)
54435       DETECT=.TRUE.
54440    ENDIF
54445   ELSE
54450    DETECT=.FALSE.
54455    DETTIME=TIME2
54460 ENDIF
54465
54470 RETURN
54475 END
54480 FUNCTION RAN(IY)
54485*   THIS FUNCTION RETURNS A RANDOM NUMBER.
54490 RAN=RANF()
54495 RETURN
54500 END
54505 SUBROUTINE LEAKRT(ONGO,COMP,STAGE,LKRUP,RATE,DIAM,WIDTH,LENGTH)
54510*   THIS ROUTINE ESTIMATES THE RELEASE RATE.
54515 COMMON/CRAD/CRADLE
54520 LOGICAL CRADLE
54525 COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
54530 LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
54535 LOGICAL ONGO
54540 REAL RATE,DIAM,WIDTH,LENGTH
54545 INTEGER COMP,STAGE,LKRUP
54550 REAL PRES,C,PI
54555 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
54560 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPUMP,AGPIPE
54565 COMMON/WSTCON/SGRAV
54570 COMMON/PRESS/PRESS(5,5)
54575 COMMON/RUPLEN/CLENGTH(5),CWIDTH(5),CDIAM(5)
54580 REAL CLENGTH,CWIDTH,CDIAM
54585 COMMON/SEAM/SEAMLEN,SEAMWID
54590 REAL SEAMLEN,SEAMWID
54595 COMMON/LENMIN/CLENMIN(5),CWIDMIN(5),CDIMMIN(5)
54600 REAL CLENMIN,CWIDMIN,CDIMMIN
54605 COMMON/MODE/CDIMMOD(5)
54610 REAL CDIMMOD
54615 REAL PRESS,SGRAV
54620
54625 C=0.6
54630 PI=3.1416
54635
54640 PRES=PRESS(STAGE,COMP)
54645 IF(.NOT.ONGO)THEN
54650    IF(LKRUP.EQ.1)THEN
54655*      LEAK
54660        DIAM=FNBE(CDIMMOD(COMP),CDIMMIN(COMP),CDIAM(COMP))
54665       ELSEIF(LKRUP.EQ.0)THEN
54670*      RUPTURE
54675        IF(STAGE.EQ.2)THEN
54680           WLGKFAC=1.
54685        ELSE
54690           IF((COMP.EQ.4).OR.(COMP.EQ.5))THEN
54695              WLGKFAC=.65
```

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54700          ELSE
54705             WLGKFAC=1.
54710          ENDIF
54715       ENDIF
54720       LENGTH=FNU(CLENMIN(COMP),WLGKFAC*CLENGTH(COMP))
54725       WIDTH=FNU(CWIDMIN(COMP),CWIDTH(COMP))
54730       DIAM=SQRT((LENGTH*WIDTH)*4/PI)
54735       IF(LENGTH.EQ.0)LENGTH=.0001
54740       IF(WIDTH.EQ.0)WIDTH=0.0001
54745      ELSE
54750*      SEAM RUPTURE
54755       LENGTH=FNU(0.,SEAMLEN)
54760       WIDTH=FNU(0.,SEAMWID)
54765      DIAM=SQRT((LENGTH*WIDTH)*4./PI)
54770       IF(LENGTH.EQ.0)LENGTH=0.0001
54775       IF(LENGTH.EQ.0)WIDTH=0.0001
54780    ENDIF
54785    IF(DIAM.EQ.0)DIAM=0.0001
54790 ENDIF
54795 IF((AGPIPE.AND.((COMP.EQ.1).OR.(COMP.EQ.4).OR.(COMP.EQ.5))).OR.
54800+(VAULT.AND.((COMP.EQ.4).OR.(COMP.EQ.5))).OR.
54805+(COMP.EQ.2).OR.(((AGTANK.AND.CRADLE).OR.VAULT).AND.(COMP.EQ.3))
54810+)THEN
54815    DIAM=DIAM/12.
54820    RATE=C*(PI*((DIAM/2.)**2.))*SQRT(2*PRES*32.17/(SGRAV*62.4))
54825+   *60.*7.48
54830    DIAM=DIAM*12.
54835   ELSE
54840*   UGPIPE
54845    IF(LKRUP.EQ.1)THEN
54850*      LEAK
54855       DIAM=DIAM/12.
54860       CALL UGRATE(PRES,LKRUP,DIAM,0.,RATE)
54865       DIAM=DIAM*12.
54870      ELSE
54875*      RUPTURE
54880       WIDTH=WIDTH/12.
54885       LENGTH=LENGTH/12.
54890       CALL UGRATE(PRES,LKRUP,WIDTH,LENGTH,RATE)
54895       WIDTH=WIDTH*12.
54900       LENGTH=LENGTH*12.
54905    ENDIF
54910 ENDIF
54915 RETURN
54920 END
54925 SUBROUTINE CLENUP(VOL)
54930* SUMS THE TOTAL CLEAN-UP VOLUME.
54935 REAL TCLVOL,TTCVOL,VOL
54940 COMMON/CCLEAN/TCLVOL,TTCVOL
54945 TCLVOL=TCLVOL+VOL
54950 RETURN
54955 END
54960 SUBROUTINE IMMINV(COMP,STAGE,RATE,DETECT,DETTIME)
54965*IMMEDIATE INVENTORY CONTROL-- BASED ON TANK CAPACITY
54970 COMMON/OPERAT/BATCH,CONT
54975 LOGICAL BATCH,CONT
54980 COMMON/FILL/FILLRT(5),FILLTIM(5),FILLFR(5),FILLVOL(5)
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54985 COMMON/DISCH/DISCRT(5),DISCTIM(5),DISCFR(5),VEHTANK,THRUPUT
54990 REAL FILLRT,FILLTIM,FILLFR,FILLVOL
54995 REAL DISCRT,DISCTIM,DISCFR,VEHTANK,THRUPUT
55000 COMMON/DISCVOL/DISCVOL(5)
55005 REAL DISCVOL
55010 COMMON/TKINFO/FRACTUG,TNKCAP(3)
55015 REAL TNKCAP
55020 REAL RATE,DETTIME,RELVOL,DAYVOL
55025 LOGICAL DETECT
55030 INTEGER COMP,STAGE
55035 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
55040
55045 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPUMP,AGPIPE
55050 COMMON/INVEN/MINVLIM,IINVLIM,WINVLIM
55055 REAL MINVLIM,IINVLIM,WINVLIM
55060 DETECT=.FALSE.
55065 IF((COMP.EQ.1).OR.(COMP.EQ.2).OR.(COMP.EQ.4).OR.(COMP.EQ.5))THEN
55070    IF(STAGE.EQ.1)THEN
55075        RELVOL=RATE*FILLTIM(STAGE)*FILLFR(STAGE)
55080  IF(RELVOL.GT.FILLVOL(1)*FILLFR(1))RELVOL=FILLVOL(1)*FILLFR(1)
55085        IF(RELVOL.GE.(IINVLIM*TNKCAP(1))) DETECT=.TRUE.
55090     ELSE
55095        RELVOL=RATE*DISCTIM(STAGE)*DISCFR(STAGE)
55100 IF((RELVOL.GT.DISCVOL(STAGE)*DISCFR(STAGE)).AND.BATCH)RELVOL=
55105+DISCVOL(STAGE)*DISCFR(STAGE)
55110        IF(RELVOL.GE.(IINVLIM*TNKCAP(1))) DETECT=.TRUE.
55115    ENDIF
55120 ENDIF
55125 IF(COMP.EQ.3)THEN
55130    RELVOL=RATE*24.*60.
55135        IF(RELVOL.GT.TNKCAP(1))RELVOL=TNKCAP(1)
55140    IF(RELVOL.GE.(IINVLIM*TNKCAP(1))) DETECT=.TRUE.
55145 ENDIF
55150 IF(DETECT)THEN
55155    DETTIME=FNU(24.*60.,48.*60.)
55160 ENDIF
55165 RETURN
55170 END
55175
55180 SUBROUTINE UGRATE(PRESS,LKRUP,DHOLE,LENGTH,LEAKRT)
55185*   ESTIMATES RELEASE RATES FOR FAILURES THAT RELEASE INTO
55190*   THE SOIL.
55195 LOGICAL BAKFILL
55200 COMMON/BAKFILL/BAKFILL(4)
55205
55210 REAL DHOLE,PRESS,LENGTH
55215 COMMON/SOILCH/SPHER,VOID,DPART
55220 REAL SPHER,VOID,DPART
55225 COMMON/CHARAC/DENS,VISCOS
55230 REAL DENS,VISCOS
55235 REAL PI,VEL
55240 REAL LEAKRT,A,B,C,L
55245* ENGLISH UNITS LB/FT3,FT,GALLONS/HOUR
55250 PI=3.1416
55255 IF(LKRUP.EQ.1)THEN
55260*   LEAK
55265 IF(BAKFILL(1))THEN
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55270     L=2*DHOLE
55275     IF(L.GT.(2./(2.54*12.)))  L=2./(2.54*12.)
55280    ELSEIF(BAKFILL(2))THEN
55285     L=7.5*DHOLE
55290     IF(L.GT.(10./(2.54*12.)))  L=10./(2.54*12.)
55295    ELSEIF(BAKFILL(3))THEN
55300      L=20.*DHOLE
55305        IF(L.GT.(20./(2.54*12.)))  L=20./(2.54*12.)
55310    ELSE
55315      L=100.*DHOLE
55320      IF(L.GT.(100./(2.54*12.)))  L=100./(2.54*12.)
55325 ENDIF
55330    ELSE
55335*    RUPTURE
55340     IF(BAKFILL(1))THEN
55345        L=4*DHOLE
55350        IF(L.GT.(4./(2.54*12.)))  L=4./(2.54*12.)
55355       ELSEIF(BAKFILL(2))THEN
55360        L=10.*DHOLE
55365        IF(L.GT.(20./(2.54*12.)))  L=20./(2.54*12.)
55370       ELSEIF(BAKFILL(3))THEN
55375        L=40.*DHOLE
55380        IF(L.GT.(40./(2.54*12.)))  L=40./(2.54*12.)
55385       ELSE
55390        L=100.*DHOLE
55395        IF(L.GT.(100./(2.54*12.)))  L=100./(2.54*12.)
55400     ENDIF
55405 ENDIF
55410 A=1.75*((1-VOID)/(VOID**3))*(DENS/(SPHER*DPART))
55415 B=(150*((1-VOID)**2)/(VOID**3))*(VISCOS/((SPHER*DPART)**2))
55420     C=PRESS*32.17/L
55425     VEL=(-B+SQRT(B**2+4*A*C))/(2*A)
55430 IF(LKRUP.EQ.1)THEN
55435     LEAKRT=60.*VEL*PI*(DHOLE**2)*7.48/4.
55440 ELSE
55445     LEAKRT=60.*VEL*DHOLE*LENGTH*7.48
55450 ENDIF
55455 END
55460 SUBROUTINE SETOPAR
55465*    SETS THE OPERATING PARAMETERS
55470 COMMON/PH/PH(5)
55475 REAL PH
55480 COMMON/DISCVOL/DISCVOL(5)
55485 REAL DISCVOL
55490 COMMON/EFFIC/TRTEFF,DVOLFR
55495 REAL TRTEFF,DVOLFR
55500 COMMON/TECH/NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
55505 LOGICAL NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
55510 COMMON/LOOPCT/NPI,NTK
55515 INTEGER NPI,NTK
55520 COMMON/TKFRAC/TANKTIM(3)
55525 REAL TANKTIM
55530 COMMON/TKGEOM/HORIZ,VERT
55535 LOGICAL HORIZ,VERT
55540 COMMON/OPERAT/BATCH,CONT
55545 LOGICAL BATCH,CONT
55550 COMMON/OPHRS/OPHRSDY
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55555 REAL OPHRSDY
55560 INTEGER OPDYYR
55565 COMMON/OPDAY/OPDYYR
55570 REAL PIPLEN,TOTBAT
55575 COMMON/PIPEDM/PIPLEN(5)
55580 INTEGER DAYSTOR
55585 REAL NUMBAT
55590 COMMON/BTCHIN/NUMBAT,DAYSTOR
55595 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
55600 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
55605 LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
55610 COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
55615 REAL TXLNGTH,TXWIDTH,TXDEPTH,PXLNGTH,PXWIDTH,PXDEPTH
55620 COMMON/EXCAVAT/TXLNGTH(3),TXWIDTH(3),TXDEPTH(3),PXLNGTH(5),
55625+      PXWIDTH(5),PXDEPTH(5)
55630 REAL TLENGTH,TWIDTH,THEIGHT,UGTHGHT,AGTHGHT,DIAM,LENGTH
55635 COMMON/TANKDM/TLENGTH(3),TWIDTH(3),THEIGHT(3),UGTHGHT(3),
55640+AGTHGHT(3),DIAM(3),LENGTH(3)
55645 REAL FRACTUG,TNKCAP
55650 COMMON/TKINFO/FRACTUG,TNKCAP(3)
55655 REAL PRESS
55660 COMMON/PRESS/PRESS(5,5)
55665 REAL FILLRT,FILLTIM,FILLFR,FILLVOL
55670 COMMON/FILL/FILLRT(5),FILLTIM(5),FILLFR(5),FILLVOL(5)
55675 COMMON/CHARAC/DENS,VISCOS
55680 REAL DENS
55685 REAL DISCRT,DISCTIM,DISCFR,VEHTANK,THRUPUT
55690 COMMON/DISCH/DISCRT(5),DISCTIM(5),DISCFR(5),VEHTANK,THRUPUT
55695 IF(STORAGE)THEN
55700 DISCFR(2)=1./DAYSTOR
55705 TANKTIM(1)=1.
55710 IF(BATCH)THEN
55715          FILLFR(1)=NUMBAT
55720          TOTBAT=DAYSTOR*FILLFR(1)
55725     FILLVOL(1)=TNKCAP(1)/TOTBAT
55730    IF(UGTANK)THEN
55735     FILLRT(1)=314.1931*SQRT(3.)/SQRT(.5+(.054*PIPLEN(1)))
55740    ELSE
55745    FILLRT(1)=100.
55750    IF(TNKCAP(1).LE.1000)FILLRT(1)=25.
55755    ENDIF
55760     FILLTIM(1)=FILLVOL(1)/FILLRT(1)
55765     VEHTANK=6000.
55770    IF(TNKCAP(1).LT.6000.)VEHTANK=TNKCAP(1)
55775     DISCVOL(2)=VEHTANK
55780     DISCRT(2)=100.
55785       IF(TNKCAP(1).LE.1000)DISCRT(2)=25.
55790     DISCTIM(2)=TNKCAP(1)/DISCRT(2)
55795   ELSE
55800*    CONTINUOUS FLOW
55805    FILLFR(1)=1.
55810    FILLTIM(1)=OPHRSDY*60.
55815    FILLVOL(1)=THRUPUT/365.
55820       FILLRT(1)=FILLVOL(1)/(24.*60.)
55825    DISCFR(1)=1.
55830    DISCTIM(2)=OPHRSDY*60.
55835    DISCVOL(2)=THRUPUT/365.
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55840    DISCRT(2)=DISCVOL(2)/(24.*60.)
55845 ENDIF
55850 ELSE
55855      IF(CHRED .OR.  CYNOX .OR.  PRECIP)THEN
55860*        CONTINUOUS FLOW ONLY
55865       DO 10 I=1,5
55870         IF(I.EQ.1)THEN
55875           FILLFR(I)=1.
55880           FILLRT(I)=TNKCAP(1)*.8/(.5*60.)
55885           THRUPUT=FILLRT(I)*60.*OPHRSDY*OPDYYR
55890           FILLVOL(I)=THRUPUT/365.
55895           FILLTIM(I)=OPHRSDY*60.
55900           DISCRT(I)=FILLRT(I)
55905           DISCTIM(I)=FILLTIM(I)
55910           DISCVOL(I)=FILLVOL(I)
55915           DISCFR(I)=FILLFR(I)
55920         ELSE
55925           DISCFR(I)=FILLFR(I)
55930           DISCTIM(I)=FILLTIM(I)
55935         IF(I.EQ.4)THEN
55940           DISCVOL(I)=.5*DISCVOL(3)
55945           DISCRT(I)=.5*DISCRT(3)
55950         ELSEIF(I.EQ.5)THEN
55955           DISCVOL(I)=.5*DISCVOL(3)
55960           DISCRT(I)=.5*DISCRT(3)
55965         ELSE
55970           DISCVOL(I)=FILLVOL(I)
55975           DISCRT(I)=FILLRT(I)
55980         ENDIF
55985           FILLRT(I)=DISCRT(I)
55990            FILLTIM(I)=DISCTIM(I)
55995            FILLVOL(I)=DISCVOL(I)
56000            FILLRT(I)=DISCRT(I)
56005         ENDIF
56010 10    CONTINUE
56015      TANKTIM(1)=OPDYYR/365.*OPHRSDY/24.
56020      TANKTIM(2)=OPDYYR/365.*OPHRSDY/24.
56025      TANKTIM(3)=OPDYYR/365.*OPHRSDY/24.
56030      ENDIF
56035      IF(CHRED)THEN
56040        IF(PH(1).GE.2.  .AND.  PH(1).LE.3.)THEN
56045          PH(2)=PH(1)
56050        ELSEIF(PH(1).GT.3.)THEN
56055          PH(2)=3.
56060        ELSE
56065          PH(2)=2.
56070        ENDIF
56075      ELSEIF(CYNOX)THEN
56080        IF(PH(1).LE.11.  .AND.  PH(1).GE.9.)THEN
56085          PH(2)=PH(1)
56090        ELSEIF(PH(1).LT.9.)THEN
56095          PH(2)=9.
56100        ELSE
56105          PH(2)=11.
56110        ENDIF
56115      ELSE
56120*       PRECIPITATION
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         IF(PH(1).GE.6.   .AND.  PH(1).LE.7)THEN
           PH(2)=PH(1)
         ELSEIF(PH(1).GT.7)THEN
           PH(1)=7
         ELSE
           PH(1)=6
         ENDIF
      ENDIF
      PH(3)=6.
      PH(4)=6.
      PH(5)=6.
      IF(DISTILL)THEN
        DO 20 I=1,5
           IF(I.EQ.5)THEN
            PH(I)=0.
            DISCRT(I)=0.
            DISCTIM(I)=0.
            DISCVOL(I)=0.
            DISCFR(I)=0.
           ELSEIF(I.EQ.1)THEN
            FILLFR(I)=NUMBAT
            FILLRT(I)=100.
            IF(TNKCAP(1).LE.1000.)  FILLRT(I)=25.
            FILLVOL(I)=TNKCAP(1)*.8
            FILLTIM(I)=TNKCAP(1)*.8/FILLRT(I)
            DISCRT(I)=FILLRT(I)
            DISCFR(I)=FILLFR(I)
            DISCVOL(I)=FILLVOL(I)
            DISCTIM(I)=FILLTIM(I)
           ELSEIF(I.EQ.2)THEN
            DISCRT(I)=TNKCAP(1)*TRTEFF*DVOLFR/(4.*60.)
            DISCVOL(I)=TNKCAP(1)*TRTEFF*DVOLFR
            DISCTIM(I)=4.*60.
            DISCFR(I)=NUMBAT
            FILLRT(I)=DISCRT(I)
            FILLTIM(I)=DISCTIM(I)
            FILLVOL(I)=DISCVOL(I)
            FILLFR(I)=DISCFR(I)
           ELSEIF(I.EQ.3)THEN
            DISCFR(I)=NUMBAT
            DISCRT(I)=100.
            IF(DISCVOL(2).LE.1000.)DISCRT(I)=25.
            DISCVOL(I)=DISCVOL(2)
            DISCTIM(I)=DISCVOL(I)/DISCRT(I)
           FILLFR(I)=DISCFR(I)
           FILLTIM(I)=DISCTIM(I)
           FILLRT(I)=DISCRT(I)
           FILLVOL(I)=DISCVOL(I)
           ELSE
            I.EQ.4
            DISCFR(I)=NUMBAT
      DISCVOL(I)=(1-TRTEFF)*FILLVOL(1)*DVOLFR+FILLVOL(1)*(1-DVOLFR)
            DISCRT(I)=100.
            IF(DISCVOL(I).LE.1000.)  DISCRT(I)=25.
            DISCTIM(I)=DISCVOL(I)/DISCRT(I)
           ENDIF
20      CONTINUE
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```
        TANKTIM(1)=4.*NUMBAT/24.*OPDYYR/365.
        TANKTIM(2)=4.*NUMBAT/24.*OPDYYR/365.
      ENDIF
ENDIF
END
 FUNCTION FNU(A,B)
*   UNIFORM PROBABILITY DISTRIBUTION
COMMON/AX/IY
IF(A.GT.B)THEN
  FNU=B
ELSE
FNU=A+RAN(IY)*(B-A)
ENDIF
RETURN
END
SUBROUTINE SETCOST(L)
*   CALCULATE THE EXCAVATION DEPTHS, HEIGHTS AND WIDTHS.
COMMON/LOOPCT/NPI,NTK
INTEGER NPI,NTK
COMMON/CRAD/CRADLE
LOGICAL CRADLE
INTEGER L
COMMON/FLORTHK/FLORTHK
COMMON/WALL/TK2WALL,PI2WALL
LOGICAL TK2WALL,PI2WALL
COMMON/LIN/LINER
LOGICAL LINER
REAL PI,GAL,FT
LOGICAL HORIZ,VERT
COMMON/TKGEOM/HORIZ,VERT
LOGICAL CONVTPD,ASPVTPD
COMMON/OTHSEC/CONVTPD,ASPVTPD
LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH, CONCRT
COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
LOGICAL CONCPAD, ASPHPAD
COMMON/TKCONT/CONCPAD,ASPHPAD
LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
REAL TXLNGTH,TXWIDTH,TXDEPTH,PXLNGTH,PXWIDTH,PXDEPTH
COMMON/EXCAVAT/TXLNGTH(3),TXWIDTH(3),TXDEPTH(3),PXLNGTH(5),
+      PXWIDTH(5),PXDEPTH(5)
C
REAL TLENGTH,TWIDTH,THEIGHT,UGTHGHT,AGTHGHT,DIAM,LENGTH
COMMON/TANKDM/TLENGTH(3),TWIDTH(3),THEIGHT(3),UGTHGHT(3),
+AGTHGHT(3),DIAM(3),LENGTH(3)
REAL PIPLEN
COMMON/PIPEDM/PIPLEN(5)
REAL TANKSA
COMMON/AREAS/TANKSA(3)
COMMON/AREAS2/PIPESA(5)
REAL PIPESA
COMMON/DIAM/PDIAM(5)
REAL PDIAM
COMMON/ITHICK/IPIPE(5),IPUMP(5),ITANK(3),IGASK(5),ITANK2(3)
REAL IPIPE,IPUMP,ITANK,IGASK,ITANK2
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 REAL FRACTUG,TNKCAP
 COMMON/TKINFO/FRACTUG,TNKCAP(3)
 REAL GWDPTH
 COMMON/WATER/GWDPTH
 PARAMETER (GAL=7.48,FT=12.)
 GWDPTH=GWDPTH*3.28
 PI=3.1416
 TANKSA(L)=((PI*LENGTH(L))+((PI/2.)*DIAM(L)))*DIAM(L)
 IF(AGTANK.AND..NOT.(CRADLE))TANKSA(L)=(PI*DIAM(L)**2)/4.
 IF (VERT) THEN
    TLENGTH(L)=DIAM(L)
    THEIGHT(L)=LENGTH(L)
    TWIDTH(L)=DIAM(L)
 ELSE
    TLENGTH(L)=LENGTH(L)
    TWIDTH(L)=DIAM(L)
    THEIGHT(L)=DIAM(L)
 ENDIF
C
 IF (IGTANK) THEN
    UGTHGHT(L)=FRACTUG*THEIGHT(L)
    AGTHGHT(L)=THEIGHT(L)-UGTHGHT(L)
 ELSEIF (AGTANK) THEN
    FRACTUG=0
    UGTHGHT(L)=0
    AGTHGHT(L)=THEIGHT(L)
 ELSE
    FRACTUG=1
    AGTHGHT(L)=0
    UGTHGHT(L)=THEIGHT(L)
 ENDIF
 IF(IGTANK)TANKSA(L)=(UGTHGHT(L)*PI*DIAM(L))+(PI/4.)
+*DIAM(L)**2.
 IF (TNKCAP(L).LE.5000) THEN
    FLORTHK=8/FT
 ELSE
    FLORTHK=12/FT
 ENDIF
 IF (UGTANK) THEN
    IF((ULVAULT.OR.LVAULT).AND..NOT.LINER)THEN
       TXLNGTH(L)=TLENGTH(L)+7.33
       TXWIDTH(L)=TWIDTH(L)+7.33
       TXDEPTH(L)=THEIGHT(L)+8
    ELSE
C   ..............NOSECON,LINER, OR TK2WALL............
       TXDEPTH(L)=THEIGHT(L)+3
         TXLNGTH(L)=TLENGTH(L)+4
         TXWIDTH(L)=TWIDTH(L)+4
          ENDIF
 ELSE
C   ............AG OR IG......................
    TXDEPTH(L)=UGTHGHT(L)+1
    IF (AGTANK) THEN
       IF (ASPHPAD.OR.CONCPAD) THEN
          TXLNGTH(L)=(TNKCAP(L)/(1.5*GAL))**0.5+3
          TXWIDTH(L)=TXLNGTH(L)
       ELSE
```

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C  .........:NOSECON OR TK2WALL.........................
         TXLNGTH(L)=TLENGTH(L)+4
         TXWIDTH(L)=TWIDTH(L)+4
      ENDIF
   ELSE
C
C   ............IG TANK..............................
      IF (ASPVTPD.OR.CONVTPD) THEN
         TXLNGTH(L)=TLENGTH(L)+7.33
         TXWIDTH(L)=TWIDTH(L)+7.33
      ELSE
C  ...............NOSECON OR TK2WALL.........................
         TXLNGTH(L)=TLENGTH(L)+4
         TXWIDTH(L)=TWIDTH(L)+4
      ENDIF
   ENDIF
ENDIF
IF(L.EQ.1)GWDPTH=GWDPTH/3.28
DO 222 M=1,NPI
 IF(UGPIPE)THEN
    PXLNGTH(M)=PIPLEN(M)
            PXWIDTH(M)=2
            PXDEPTH(M)=2
  ELSE
   PXLNGTH(M)=0
   PXWIDTH(M)=0
   PXDEPTH(M)=0
ENDIF
PIPESA(M)=(PI*(PDIAM(M)+(2*IPIPE(M)))/12.)*PIPLEN(M)
222 CONTINUE
RETURN
END
SUBROUTINE REPLAC(COMP,LOCATN)
*  REPLACE COMPONENTS AND RESAMPLE TIME-TO-FAILURE NUMBERS.
COMMON/PI2TIM/DIKTIM(5),CURTIM(5),PASPTIM(5),PCOPTIM(5),PLINTIM(5)
REAL DIKTIM,CURTIM,PASPTIM,PCOPTIM,PLINTIM
COMMON/PIPCON/DIKE,CURB,ASPAD,COPAD,PLINER
LOGICAL DIKE,CURB,ASPAD,COPAD,PLINER
COMMON/CONCTM/CONCTIM(3)
REAL CONCTIM
COMMON/FLORTHK/FLORTHK
COMMON/SECMAIN/MAINT
LOGICAL MAINT
COMMON/IYRNO/IYRNUM
COMMON/TIME/APADTIM(3),CPADTIM(3),VLTTIM(3),CBRMTIM(3),ABRMTIM(3)
REAL APADTIM,CPADTIM,VLTTIM,CBRMTIM,ABRMTIM
COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
COMMON/TKCONT/CONCPAD,ASPHPAD
LOGICAL CONCPAD,ASPHPAD
COMMON/BERM/CBERM,ABERM
LOGICAL CBERM,ABERM
COMMON/COATIM/ICOATIM(3,5),ECOATIM(3,5)
REAL ICOATIM,ECOATIM
INTEGER IYRNUM
REAL CATTIM
COMMON/CATMAIN/MAINTEN
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REAL MAINTEN
LOGICAL CATFAIL
COMMON/CATSYS/CATTIM
COMMON/CATHOD/CATFAIL
INTEGER TANKAGE
COMMON/TANKAGE/TANKAGE
INTEGER LOCATN,COMP
LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
LOGICAL COATING
COMMON/COATS/COATING(4,3,5)
COMMON/ALARM/INTERST(5,2),INTER,PIINTER(5,2),PINTER
REAL INTERST,INTER,PIINTER,PINTER
IF (COMP.EQ.1) THEN
      CALL COATS(1,LOCATN)
      PIINTER(LOCATN,1)=PINTER
   IF(DIKE.AND.(DIKTIM(LOCATN).LE.IYRNUM))THEN
      CALL SECCON(2,1.,MAINT,DIKTIM(LOCATN))
      DIKTIM(LOCATN)=DIKTIM(LOCATN)+IYRNUM
   ENDIF
   IF(CURB.AND.(CURTIM(LOCATN).LE.IYRNUM))THEN
      CALL SECCON(4,1.,MAINT,CURTIM(LOCATN))
      CURTIM(LOCATN)=CURTIM(LOCATN)+IYRNUM
   ENDIF
   IF(COPAD.AND.(PCOPTIM(LOCATN).LE.IYRNUM))THEN
      CALL SECCON(3,.667,MAINT,PCOPTIM(LOCATN))
      PCOPTIM(LOCATN)=PCOPTIM(LOCATN)+IYRNUM
   ENDIF
   IF(ASPAD.AND.(PASPTIM(LOCATN).LE.IYRNUM))THEN
      CALL SECCON(1,.667,MAINT,PASPTIM(LOCATN))
      PASPTIM(LOCATN)=PASPTIM(LOCATN)+IYRNUM
   ENDIF
ELSEIF (COMP.EQ.2) THEN
      CALL COATS(2,LOCATN)
ELSEIF (COMP.EQ.3) THEN
  TANKAGE=0
   CALL COATS(3,1)
   IF(CATSTEL)THEN
   IF(COATING(2,3,1))THEN
   CATTIM=FNN(10.,5.)*MAINTEN+IYRNUM+
+ ((ECOATIM(COMP,LOCATN)-IYRNUM)*FNB(.5))
  ELSE
     CATTIM=FNN(10.,5.)*MAINTEN+IYRNUM
ENDIF
ENDIF
INTERST(LOCATN,1)=INTER
IF(CONCRT)CONCTIM(LOCATN)=FNN(35.,10.)+IYRNUM
IF(VAULT.AND.(VLTTIM(LOCATN).LE.IYRNUM))THEN
CALL SECCON(5,FLORTHK,MAINT,VLTTIM(LOCATN))
VLTTIM(LOCATN)=VLTTIM(LOCATN)+IYRNUM
ENDIF
IF(CONCPAD.AND.(CPADTIM(LOCATN).LE.IYRNUM))THEN
CALL SECCON(3,FLORTHK,MAINT,CPADTIM(LOCATN))
CPADTIM(LOCATN)=CPADTIM(LOCATN)+IYRNUM
ENDIF
IF(ASPHPAD.AND.(APADTIM(LOCATN).LE.IYRNUM))THEN
CALL SECCON(1,FLORTHK,MAINT,APADTIM(LOCATN))
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57550 APADTIM(LOCATN)=APADTIM(LOCATN)+IYRNUM
57555 ENDIF
57560 IF(CBERM.AND.(CBRMTIM(LOCATN).LE.IYRNUM))THEN
57565 CALL SECCON(4,1.,MAINT,CBRMTIM(LOCATN))
57570 CBRMTIM(LOCATN)=CBRMTIM(LOCATN)+IYRNUM
57575 ENDIF
57580 IF(ABERM.AND.(ABRMTIM(LOCATN).LE.IYRNUM))THEN
57585 CALL SECCON(2,1.,MAINT,ABRMTIM(LOCATN))
57590 ABRMTIM(LOCATN)=ABRMTIM(LOCATN)+IYRNUM
57595 ENDIF
57600 ELSEIF (COMP.EQ.6)THEN
57605     IF(DIKE)THEN
57610         CALL SECCON(2,1.,MAINT,DIKTIM(LOCATN))
57615         DIKTIM(LOCATN)=DIKTIM(LOCATN)+IYRNUM
57620     ENDIF
57625     IF(CURB)THEN
57630         CALL SECCON(4,1.,MAINT,CURTIM(LOCATN))
57635         CURTIM(LOCATN)=CURTIM(LOCATN)+IYRNUM
57640     ENDIF
57645     IF(COPAD)THEN
57650         CALL SECCON(3,.667,MAINT,PCOPTIM(LOCATN))
57655         PCOPTIM(LOCATN)=PCOPTIM(LOCATN)+IYRNUM
57660     ENDIF
57665     IF(ASPAD)THEN
57670         CALL SECCON(1,.667,MAINT,PASPTIM(LOCATN))
57675         PASPTIM(LOCATN)=PASPTIM(LOCATN)+IYRNUM
57680     ENDIF
57685 ELSEIF (COMP.EQ.7) THEN
57690 IF(VAULT)THEN
57695 CALL SECCON(5,FLORTHK,MAINT,VLTTIM(LOCATN))
57700 VLTTIM(LOCATN)=VLTTIM(LOCATN)+IYRNUM
57705 ENDIF
57710 IF(CONCPAD)THEN
57715 CALL SECCON(3,FLORTHK,MAINT,CPADTIM(LOCATN))
57720 CPADTIM(LOCATN)=CPADTIM(LOCATN)+IYRNUM
57725 ENDIF
57730 IF(ASPHPAD)THEN
57735 CALL SECCON(1,FLORTHK,MAINT,APADTIM(LOCATN))
57740 APADTIM(LOCATN)=APADTIM(LOCATN)+IYRNUM
57745 ENDIF
57750 IF(CBERM)THEN
57755 CALL SECCON(4,1.,MAINT,CBRMTIM(LOCATN))
57760 CBRMTIM(LOCATN)=CBRMTIM(LOCATN)+IYRNUM
57765 ENDIF
57770 IF(ABERM)THEN
57775 CALL SECCON(2,1.,MAINT,ABRMTIM(LOCATN))
57780 ABRMTIM(LOCATN)=ABRMTIM(LOCATN)+IYRNUM
57785 ENDIF
57790 ELSEIF (COMP.EQ.8) THEN
57795         CALL COATS(8,1)
57800   TANKAGE=0
57805 IF(CONCRT)CONCTIM(LOCATN)=FNN(35.,10.)+IYRNUM
57810     IF(COATING(2,3,1).AND.CATSTEL)THEN
57815         CATTIM=FNN(10.,5.)*MAINTEN+IYRNUM+
57820+ ((ECOATIM(3,1)-IYRNUM)*FNB(.5))
57825     ELSE
57830       CATTIM=FNN(10.,5.)*MAINTEN+IYRNUM
```

```
  ENDIF
      CATFAIL=.FALSE.
          TANKAGE=0
DO 22591 L=1,5
   INTERST(L,1)=INTER
   PIINTER(L,1)=PINTER
22591 CONTINUE
   IF(DIKE)THEN
      CALL SECCON(2,1.,MAINT,DIKTIM(LOCATN))
      DIKTIM(LOCATN)=DIKTIM(LOCATN)+IYRNUM
   ENDIF
   IF(CURB)THEN
      CALL SECCON(4,1.,MAINT,CURTIM(LOCATN))
      CURTIM(LOCATN)=CURTIM(LOCATN)+IYRNUM
   ENDIF
   IF(COPAD)THEN
      CALL SECCON(3,.667,MAINT,PCOPTIM(LOCATN))
      PCOPTIM(LOCATN)=PCOPTIM(LOCATN)+IYRNUM
   ENDIF
   IF(ASPAD)THEN
      CALL SECCON(1,.667,MAINT,PASPTIM(LOCATN))
      PASPTIM(LOCATN)=PASPTIM(LOCATN)+IYRNUM
   ENDIF
IF(VAULT)THEN
CALL SECCON(5,FLORTHK,MAINT,VLTTIM(LOCATN))
VLTTIM(LOCATN)=VLTTIM(LOCATN)+IYRNUM
ENDIF
IF(CONCPAD)THEN
CALL SECCON(3,FLORTHK,MAINT,CPADTIM(LOCATN))
CPADTIM(LOCATN)=CPADTIM(LOCATN)+IYRNUM
ENDIF
IF(ASPHPAD)THEN
CALL SECCON(1,FLORTHK,MAINT,APADTIM(LOCATN))
APADTIM(LOCATN)=APADTIM(LOCATN)+IYRNUM
ENDIF
IF(CBERM)THEN
CALL SECCON(4,1.,MAINT,CBRMTIM(LOCATN))
CBRMTIM(LOCATN)=CBRMTIM(LOCATN)+IYRNUM
ENDIF
IF(ABERM)THEN
CALL SECCON(2,1.,MAINT,ABRMTIM(LOCATN))
ABRMTIM(LOCATN)=ABRMTIM(LOCATN)+IYRNUM
ENDIF
C
ELSEIF (COMP.EQ.9) THEN
      CATTIM=FNN(10.,5.)*MAINTEN+IYRNUM
      CATFAIL=.FALSE.
ELSE
ENDIF
RETURN
END
SUBROUTINE SETVAP(COMP,VTIME,VAPWDIS,LOWER)
*   ESTIMATE THE VAPOR TRANSPORT TIMES -- THIS IS THE TIME
*   IT TAKES FOR THE VAPOR TO REACH THE DETECTION CONCENTRATION
*   AT THE MONITORING POINT.
LOGICAL BAKFILL
COMMON/BAKFILL/BAKFILL(4)
```

```
58120 REAL TORTFAC,DIFF1,DIFF2,E,VAPRESS,DIFFI,LOWER
58125 REAL Z,FOFZ,VTIME,TIME
58130 LOGICAL SOIL
58135 INTEGER COMP
58140 REAL TXWIDTH
58145 REAL VAPWDIS
58150 COMMON/SOILTYP/SOIL(4)
58155 COMMON/MASSDIF/DIFFI,DIFF1,DIFF2,VAPRESS
58160 IF(SOIL(1)) E=0.20
58165 IF(SOIL(2)) E=0.08
58170 IF(SOIL(3)) E=0.26
58175 IF(SOIL(4)) E=0.16
58180 IF(BAKFILL(1)) BE=.20
58185 IF(BAKFILL(2)) BE=.08
58190 IF(BAKFILL(3)) BE=.26
58195 IF(BAKFILL(4)) BE=.16
58200 TORTFAC=1/(3**0.5)
58205 VAPWDIS=VAPWDIS/3.28
58210 DIFF2=DIFFI*TORTFAC*E
58215 DIFF1=DIFFI*TORTFAC*BE
58220 FOFZ=(VAPRESS-LOWER)/VAPRESS
58225 CALL ERF(Z,FOFZ,1)
58230 IF (COMP.EQ.3) THEN
58235     VTIME=((VAPWDIS/Z)**2)/(4*DIFF1)
58240  ELSE
58245     VTIME=((VAPWDIS/Z)**2)/(4*DIFF2)
58250 ENDIF
58255 VTIME=VTIME/60
58260 VAPWDIS=VAPWDIS*3.28
58265 RETURN
58270 END
58275 SUBROUTINE ERF(Z,FOFZ,K)
58280*   INTERPOLATION OF THE ERROR FUNCTION.
58285 REAL DZ(114),DERFZ(114),Z,FOFZ
58290 INTEGER K
58295 DATA(DZ(J),J=1,12)/3.6,3.4,3.2,3.1,2.9,2.8,2.6,2.6,2.5,2.4,2.3,2.2
58300+/
58305 DATA(DZ(J),J=13,22)/2.1,2.0,1.98,1.96,1.94,1.92,1.90,1.88,1.86,1.8
58310+4/
58315 DATA(DZ(J),J=23,32)/1.82,1.8,1.78,1.76,1.74,1.72,1.7,1.68,1.66,1.6
58320+4/
58325 DATA(DZ(J),J=33,42)/1.62,1.6,1.58,1.56,1.54,1.52,1.5,1.48,1.46,1.4
58330+4/
58335 DATA(DZ(J),J=43,52)/1.42,1.4,1.38,1.36,1.34,1.32,1.3,1.28,1.26,1.2
58340+4/
58345 DATA(DZ(J),J=53,62)/1.22,1.2,1.18,1.16,1.14,1.12,1.1,1.08,1.06,1.0
58350+4/
58355 DATA(DZ(J),J=63,74)/1.02,1.,.98,.96,.94,.92,.9,.88,.86,.84,.82,.8/
58360 DATA(DZ(J),J=75,87)/.78,.76,.74,.72,.7,.68,.66,.64,.62,.6,.58,.56,
58365+.54/
58370 DATA(DZ(J),J=88,100)/.52,.5,.48,.46,.44,.42,.4,.38,.36,.34,.32,.3,
58375+.28/
58380 DATA(DZ(J),J=101,111)/.26,.24,.22,.2,.18,.16,.14,.12,.1,.08,.06/
58385 DATA(DZ(J),J=112,114)/.04,.02,0/
58390 DATA(DERFZ(J),J=1,6)/1.,.999998,.999994,.999978,.999959,.999925/
58395 DATA(DERFZ(J),J=7,11)/.999866,.999764,.999593,.999311,.998857/
58400 DATA(DERFZ(J),J=12,16)/.998137,.997020,.995322,.99489,.99443/
```

```
58405 DATA(DERFZ(J),J=17,21)/.99392,.99338,.99279,.99216,.99147/
58410 DATA(DERFZ(J),J=22,26)/.99074,.98994,.98909,.98817,.98719/
58415 DATA(DERFZ(J),J=27,31)/.98613,.98500,.98379,.98249,.98110/
58420 DATA(DERFZ(J),J=32,36)/.97962,.97804,.97635,.97455,.97263/
58425 DATA(DERFZ(J),J=37,41)/.97059,.96841,.96610,.96365,.96105/
58430 DATA(DERFZ(J),J=42,46)/.95830,.95538,.95228,.94902,.94556/
58435 DATA(DERFZ(J),J=47,51)/.94191,.93806,.93401,.92973,.92524/
58440 DATA(DERFZ(J),J=52,56)/.92050,.91553,.91031,.90484,.89910/
58445 DATA(DERFZ(J),J=57,61)/.89308,.88079,.88020,.87333,.86614/
58450 DATA(DERFZ(J),J=62,66)/.85865,.85084,.84270,.83423,.82542/
58455 DATA(DERFZ(J),J=67,71)/.81627,.80677,.79691,.78669,.77610/
58460 DATA(DERFZ(J),J=72,76)/.76514,.75381,.74210,.73001,.71754/
58465 DATA(DERFZ(J),J=77,81)/.70468,.69143,.67780,.66278,.64938/
58470 DATA(DERFZ(J),J=82,86)/.63459,.61941,.60386,.58792,.57162/
58475 DATA(DERFZ(J),J=87,91)/.55494,.53790,.52050,.50275,.48466/
58480 DATA(DERFZ(J),J=92,96)/.46622,.44749,.42839,.40901,.38933/
58485 DATA(DERFZ(J),J=97,101)/.36936,.34913,.32863,.30788,.28690/
58490 DATA(DERFZ(J),J=102,106)/.26570,.24430,.22270,.20094,.17901/
58495 DATA(DERFZ(J),J=107,111)/.15695,.13476,.11246,.09008,.06762/
58500 DATA(DERFZ(J),J=112,114)/.04511,.02256,.00000/
58505 IF (K.EQ.1) THEN
58510    DO 433 I=1,114
58515       IF (DERFZ(I).LE.FOFZ) GOTO 120
58520    433 CONTINUE
58525    120 CONTINUE
58530    IF (I.EQ.1) THEN
58535       Z=3.6
58540    ELSE
58545   Z=DZ(I-1)-(((DERFZ(I-1)-FOFZ)/(DERFZ(I-1)-DERFZ(I)))*(DZ(I-1)
58550+          -DZ(I)))
58555    ENDIF
58560 ELSE
58565   DO 130 I=1,114
58570       IF(DZ(I).LE.Z) GO TO 140
58575   130 CONTINUE
58580   140 CONTINUE
58585   IF(I.EQ.1) THEN
58590      FOFZ=1.0
58595   ELSE
58600      FOFZ=DERFZ(I-1)-(((DZ(I-1)-Z)/(DZ(I-1)-DZ(I)))*(DERFZ(I-1)-
58605+    DERFZ(I)))
58610 ENDIF
58615 ENDIF
58620 RETURN
58625 END
58630 SUBROUTINE VAPOR(C,T,D)
58635*  CHECKS FOR VAPOR SENSOR FAILURE.
58640 INTEGER C
58645 REAL T
58650 LOGICAL D
58655 REAL VTIME
58660 COMMON/VTIME/VTIME(3)
58665 COMMON/VAPPRB/VAPSENS,VSENSOR
58670 REAL VAPSENS,VSENSOR
58675 REAL VAPFLG
58680 IF (C.EQ.1.OR.C.EQ.6) THEN
58685    T=VTIME(1)
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```
58690 ELSEIF (C.EQ.2) THEN
58695    T=VTIME(2)
58700 ELSEIF (C.EQ.3.OR.C.EQ.4.OR.C.EQ.5.OR.C.EQ.7) THEN
58705    T=VTIME(3)
58710 ELSE
58715 ENDIF
58720 VAPFLG=FNB(VAPSENS)
58725 IF(VAPFLG.EQ.1) THEN
58730    D=.TRUE.
58735  ELSE
58740   D=.FALSE.
58745 ENDIF
58750 RETURN
58755 END
58760 SUBROUTINE PENET(COMP,Q,VOL,T)
58765*  CALCULATES THE FLUID'S DEPTH OF PENETRATION
58770*  INTO THE SOIL.
58775 REAL PMOPEN,TMOPEN
58780 COMMON/MONTHLY/PMOPEN,TMOPEN
58785 REAL AREA
58790 REAL PPNDPTH,PERM,POSZ,POR,THETA,THETAP
58795 INTEGER COMP,NFFLAG
58800 COMMON/GEOL/POSZ,THETA,NFFLAG,POR,THETAP,PERM
58805 COMMON/EXCAVAT/TXLNGTH(3),TXWIDTH(3),TXDEPTH(3),PXLNGTH(5),
58810+      PXWIDTH(5),PXDEPTH(5)
58815 REAL TXLNGTH,TXWIDTH
58820 REAL PXLNGTH,PXWIDTH
58825 IF (COMP.NE.1.AND.COMP.NE.2.AND.COMP.NE.6) THEN
58830    AREA=TXLNGTH(1)*TXWIDTH(1)
58835 ELSE
58840    AREA=PXLNGTH(1)*PXWIDTH(1)
58845    IF (AREA.EQ.0)THEN
58850       AREA=TXLNGTH(1)*TXWIDTH(1)
58855     ENDIF
58860 ENDIF
58865 IF (NFFLAG.EQ.0) THEN
58870    DEPTH1=VOL/(POR*AREA)
58875 ELSE
58880    DEPTH1=VOL/(POR*THETAP*AREA)
58885 ENDIF
58890 IF (Q.NE.0) THEN
58895 DEPTH2=(Q*T*86400./((POR-THETA)*((Q/(PERM*.01))**(POSZ/(2.+3.*POSZ
58900+)))))/.3048
58905 ELSE
58910    DEPTH2=0
58915 ENDIF
58920 IF (COMP.EQ.3) THEN
58925    TMOPEN=AMIN1(DEPTH1,DEPTH2)
58930 ELSE
58935  PMOPEN=AMIN1(DEPTH1,DEPTH2)
58940 ENDIF
58945 RETURN
58950 END
58955 SUBROUTINE SAVCALC(SAV)
58960* THIS SUBROUTINE CALCULATES SOIL AGRESSIVENESS VALUES(SAV) BASED
58965*ON  FOUR  SOIL  CHAR.:  RESISTIVITY,PH,WATER  CONTENT,  AND  SULFIDE
CONTENT.
```

```
58970 COMMON/SOIL/SATSOIL,SPH,RESIS,SULFSOL
58975 REAL RVAR,PHVAR
58980 REAL RESIS,SPH,SAV
58985 LOGICAL SATSOIL,SULFSOL
58990 SAV=0.
58995*
59000*
59005 IF(RESIS.LT.300.) SAV=SAV+12
59010 IF((RESIS.GE.300.).AND.(RESIS.LT.1000.)) SAV=SAV+10
59015 IF((RESIS.GE.1000.).AND.(RESIS.LT.2000.)) SAV=SAV+8
59020 IF((RESIS.GE.2000.).AND.(RESIS.LT.5000.)) SAV=SAV+6
59025 IF((RESIS.GE.5000.).AND.(RESIS.LT.10000.)) SAV=SAV+3
59030 IF((RESIS.GE.10000.).AND.(RESIS.LT.25000.)) SAV=SAV+1
59035*
59040*
59045 IF(SPH.LT.3.) SAV=SAV+8
59050 IF((SPH.GE.3.).AND.(SPH.LT.5.)) SAV=SAV+6
59055 IF((SPH.GE.5.).AND.(SPH.LT.6.5)) SAV=SAV+4
59060 IF((SPH.GE.6.5).AND.(SPH.LT.7.5)) SAV=SAV+2
59065 IF((SPH.GE.7.5).AND.(SPH.LT.9.)) SAV=SAV+1
59070*
59075*
59080 IF(SATSOIL)THEN
59085     H20=3
59090   ELSE
59095     H20=0
59100 ENDIF
59105 SAV=SAV+H20
59110*
59115 IF(SULFSOL) SAV=SAV+4
59120*
59125* DIFFERENTIAL SOIL CHARACTERISTICS ALSO ADD TO SAV.  THESE ARE
59130* SELECTED BASED ON A UNIFORM DISTRIBUTION.
59135*
59140 RVAR=FNU(0.,1.)
59145 PHVAR=FNU(0.,3.)
59150*
59155*RVAR IS THE LOCAL VARIATION IN RESISTIVITY;PHVAR IS THE VARIATION IN
PH.
59160*
59165 IF(RVAR.LT.0.1) SAV=SAV+3
59170 IF((RVAR.GE.0.1).AND.(RVAR.LT.0.2)) SAV=SAV+2
59175 IF((RVAR.GE.0.2).AND.(RVAR.LT.0.33)) SAV=SAV+1
59180*
59185 IF(PHVAR.GT.1.5) SAV=SAV+1
59190*
59195 RETURN
59200 END
59205* GENERATION OF RANDOM VARIATES FROM AN EMPIRICAL DISTRIBUTION
59210 REAL FUNCTION FN(A,N)
59215 DIMENSION A(N,2)
59220 COMMON/AX/IY
59225 R=RAN(IY)
59230 DO 10 I=1,N
59235 J=I+1
59240 IF(R.LE.A(J,1)) GO TO 20
59245 10 CONTINUE
```

```
59250 FN=100.
59255 GO TO 30
59260 20 FN=A(I,2)+(A(J,2)-A(I,2))*(R-A(I,1))/(A(J,1)-A(I,1))
59265 30 CONTINUE
59270 RETURN
59275 END
59280 REAL FUNCTION AGEEST(LOC,COMP)
59285*   THIS FUNCTION ESTIMATES THE TIME OF EXTERNAL CORROSION
59290*   FAILURE FOR TANKS, VAULTED PIPES AND ABOVE-GROUND PIPES.
59295 COMMON/AREAS2/PIPESA(5)
59300 REAL PIPESA
59305 INTEGER LOC
59310 COMMON/LP/LPAR,LPARPI
59315 REAL LPAR,LPARPI
59320 COMMON/SAV/SAV
59325 REAL SAV,LFLAG
59330 INTEGER COMP
59335 REAL PAGEST,PUGEST
59340 REAL APIP,BPIP,APIPAG,BPIPAG,APIPUG,BPIPUG
59345 LOGICAL LOCUGPI
59350 COMMON/LOCFLAG/LOCUGPI
59355 COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
59360 LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
59365 COMMON/COATS/COATING(4,3,5)
59370 LOGICAL COATING
59375 COMMON/SAVAGE/UGTLOW,UGTMED,UGTHIGH,AGTALL
59380 REAL UGTLOW,UGTMED,UGTHIGH,AGTALL
59385 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
59390 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
59395 DIMENSION UGTLOW(7,2),UGTMED(7,2),UGTHIGH(7,2),AGTALL(7,2)
59400 AGEEST=100.0
59405 IF(COMP.EQ.3)THEN
59410     IF((UGTANK.OR.IGTANK).AND.(.NOT.VAULT))THEN
59415     IF(SAV.LE.6.0)THEN
59420        AGEEST=FN(UGTLOW,7)
59425       ELSEIF(SAV.LE.12.0)THEN
59430        AGEEST=FN(UGTMED,7)
59435       ELSE
59440        AGEEST=FN(UGTHIGH,7)
59445     ENDIF
59450    ELSE
59455*    AGTANK OR VAULTED TANK
59460     AGEEST=FN(UGTLOW,7)
59465     ENDIF
59470 ENDIF
59475 IF(COMP.EQ.1)THEN
59480     IF(UGPIPE.AND.(.NOT.PIPSEC))THEN
59485*        THIS PART OF THE 'IF' STATEMENT IS NOT USED.  THE ROSSUM
59490*    MODEL REPLACED THIS ESTIMATE.
59495        IF(SAV.LE.6.0)THEN
59500           APIP=0.11
59505           BPIP=15.0
59510          ELSEIF(SAV.LE.12.0)THEN
59515           APIP=0.15
59520           BPIP=12.0
59525          ELSE
59530           APIP=0.18
```

```
59535          BPIP=9.6
59540       ENDIF
59545      ELSEIF(UGPIPE.AND.PIPSEC)THEN
59550*      VAULTED PIPE
59555       APIP=0.11*(.05*PIPESA(LOC)/10.47)**.16
59560       BPIP=15.0
59565      ELSE
59570*      AGPIPE
59575       APIPAG=.11*(.05*PIPESA(LOC)/10.47)**.16
59580       BPIPAG=15.0
59585      IF(UGTANK)THEN
59590       IF(SAV.LE.6.0)THEN
59595          APIPUG=.11*(.05*PIPESA(LOC)/10.47)**.16
59600          BPIPUG=15.0
59605         ELSEIF(SAV.LE.12.0)THEN
59610          APIPUG=.15*(.05*PIPESA(LOC)/10.47)**.16
59615          BPIPUG=12.0
59620         ELSE
59625          APIPUG=.18*(.05*PIPESA(LOC)/10.47)**.16
59630          BPIPUG=9.6
59635       ENDIF
59640      ENDIF
59645    ENDIF
59650    IF(UGPIPE)THEN
59655       LFLAG=FNB(APIP)
59660 IF((LFLAG.EQ.1.0).OR.(.NOT.COATING(4,COMP,1)))  AGEEST=FNN(BPIP,
59665+ .42*BPIP)
59670      ELSE
59675*      AGPIPE
59680       LOCUGPI=.FALSE.
59685       PAGEST=100.
59690       PUGEST=100.
59695       LFLAG=FNB(APIPAG)
59700  IF((LFLAG.EQ.1.0).OR.(.NOT.COATING(4,COMP,1)))  PAGEST=FNN(BPIPAG,
59705+.42*BPIPAG)
59710    IF(UGTANK)THEN
59715       LFLAG=FNB(APIPUG)
59720 IF((LFLAG.EQ.1.0).OR.(.NOT.COATING(4,COMP,1)))  PUGEST=FNN(BPIPUG,
59725+.42*BPIPUG)
59730    ENDIF
59735       IF((.NOT.PIPSEC).AND.UGTANK)THEN
59740       IF(PUGEST.LT.PAGEST)THEN
59745          AGEEST=PUGEST
59750          LOCUGPI=.TRUE.
59755         ELSE
59760          AGEEST=PAGEST
59765          LOCUGPI=.FALSE.
59770       ENDIF
59775      ELSE
59780       AGEEST=PAGEST
59785       LOCUGPI=.FALSE.
59790      ENDIF
59795    ENDIF
59800 ENDIF
59805 RETURN
59810 END
59815 SUBROUTINE SIZDIST(RVOL)
```

```
59820*   THIS ROUTINE CREATES THE VOLUME DISTRIBUTION FOR THE RELEASE
59825*  INCIDENT VOLUMES.
59830 COMMON/DISTSIZ/NSIZE(14)
59835 INTEGER NSIZE
59840 REAL RVOL
59845 IF(RVOL.LE.1.)THEN
59850     NSIZE(1)=NSIZE(1)+1
59855 ELSEIF(RVOL.LE.10.)THEN
59860     NSIZE(2)=NSIZE(2)+1
59865 ELSEIF(RVOL.LE.25.)THEN
59870     NSIZE(3)=NSIZE(3)+1
59875 ELSEIF(RVOL.LE.100.)THEN
59880     NSIZE(4)=NSIZE(4)+1
59885 ELSEIF(RVOL.LE.500.)THEN
59890     NSIZE(5)=NSIZE(5)+1
59895 ELSEIF(RVOL.LE.1000.)THEN
59900     NSIZE(6)=NSIZE(6)+1
59905 ELSEIF(RVOL.LE.3000.)THEN
59910     NSIZE(7)=NSIZE(7)+1
59915 ELSEIF(RVOL.LE.5000.)THEN
59920     NSIZE(8)=NSIZE(8)+1
59925 ELSEIF(RVOL.LE.7000.)THEN
59930     NSIZE(9)=NSIZE(9)+1
59935 ELSEIF(RVOL.LE.10000.)THEN
59940     NSIZE(10)=NSIZE(10)+1
59945 ELSEIF(RVOL.LE.20000.)THEN
59950     NSIZE(11)=NSIZE(11)+1
59955 ELSEIF(RVOL.LE.30000.)THEN
59960     NSIZE(12)=NSIZE(12)+1
59965 ELSEIF(RVOL.LE.60000.)THEN
59970     NSIZE(13)=NSIZE(13)+1
59975 ELSE
59980     NSIZE(14)=NSIZE(14)+1
59985 ENDIF
59990 RETURN
59995 END
60000 SUBROUTINE RESTART
60005*   THIS ROUTINE INITIALIZES ALL THE DETECTION OPTIONS THAT ARE
60010* STARTED IN THE BENCHMARK YEAR FOR EXISTING TANK RUNS.
60015 COMMON/MOINV/MINV,MINT
60020 REAL MINV
60025 INTEGER MINT
60030 COMMON/LOOPCT/NPI,NTK
60035 INTEGER NPI,NTK
60040 COMMON/INVEN/MINVLIM,IINVLIM,WINVLIM
60045 REAL MINVLIM,IINVLIM,WINVLIM
60050 REAL TCLVOL,TTCVOL
60055 COMMON/CCLEAN/TCLVOL,TTCVOL
60060 REAL TRVOL
60065 COMMON/RCLEAN/TRVOL
60070 COMMON/DAVOL1/LOSEVOL,OVERVOL(12),HOSEVOL,PMLKVOL(5),RPWLVOL(5)
60075 REAL LOSEVOL,OVERVOL,HOSEVOL,PMLKVOL,RPWLVOL
60080 COMMON/VOL2/ PIDEFVL(5),WLDEFVL(5),GKDEFVL(5),PILKVOL(5),GKLKVOL
60085+(5),RPPIVOL(5)
60090 REAL PIDEFVL,WLDEFVL,GKDEFVL,PILKVOL,GKLKVOL,RPPIVOL
60095 COMMON/VOL3/ TKDEFVL(3),TKLKVOL(3),RPTKVOL(3)
60100 REAL TKDEFVL,TKLKVOL,RPTKVOL
```

```
60105 COMMON/MONIT/MONMETH(7),PIPMON
60110 INTEGER FALNUM,FALNUM1,FALNUM3,FALNUM4,FALNUM7
60115 COMMON/FALNUM/FALNUM,FALNUM1(100),FALNUM2(100),FALNUM3(100),
60120+  FALNUM4(100),FALNUM5(100),FALNUM7(100)
60125 COMMON/FALNUM6/FALNUM6(100)
60130 CHARACTER FALNUM6*2
60135 REAL FALNUM2,FALNUM5
60140 REAL VOL1
60145 COMMON/LOWVOL1/VOL1
60150 COMMON/COUNT/NPIPDEF(5),NWLDDEF(5),NGSKDEF(5),NPIPLK(5),NGSKLK(5),
60155+NRUPPIP(5),NPMPLK(5),NRUPWLD(5),NTNKLK(3),NTNKDEF(3),NRUPTNK(3)
60160 REAL NPIPDEF,NWLDDEF,NGSKDEF,NPIPLK,NGSKLK,NRUPPIP,NPMPLK,NRUPWLD,
60165+      NTNKLK,NTNKDEF,NRUPTNK
60170 INTEGER CONLEAK(100)
60175 COMMON/TEMPS/TPIPMON,TTKTST,TTK1TST,TTK5TST,TTKSTST,
60180+ TPITST,TPI1TST,TPI5TST,TPISTST,TMNMETH(6),TULTRTS
60185+ ,TMINVL,TWINVL,TIINVL,EXMINV,EXWINV,EXIINV
60190 REAL TMINVL,TWINVL,TIINVL,EXMINV,EXWINV,EXIINV
60195 COMMON/TESTING/TNK1TST,TNK5TST,PIP1TST,PIP5TST
60200 LOGICAL TPIPMON,TTKTST,TTK1TST,TTK5TST,TTKSTST,TPITST,
60205+ TPI1TST,TPI5TST,TPISTST,TMNMETH,TULTRTS
60210 COMMON/AGSTART/AGPOPUL,AGTKLK
60215 INTEGER AGPOPUL,AGTKLK
60220 COMMON/VLREM/TTREMVL,TPREMVL
60225 REAL TTREMVL,TPREMVL
60230 COMMON/SEMITST/TNKSTST,PIPSTST
60235 COMMON/TSTFLAG/TKTSTG,PITSTG,ULTRTST
60240 LOGICAL TNK1TST,TNK5TST,TNKSTST,PIP1TST,PIP5TST,PIPSTST,PIPMON,
60245+  MONMETH,TKTSTG,PITSTG,ULTRTST
60250 TCLVOL=0
60255 TRVOL=0
60260 IF(FALNUM.NE.0)THEN
60265   K=0
60270   DO 100 L=1,NPI
60275         IF(NPIPDEF(L).EQ.1)THEN
60280           DO 112 II=FALNUM,1,-1
60285             IF(FALNUM1(II).EQ.(1010+L))THEN
60290               K=K+1
60295               CONLEAK(K)=II
60300               GO TO 101
60305             ENDIF
60310           112 CONTINUE
60315       ELSE
60320   PIDEFVL(L)=0
60325         ENDIF
60330     101 IF(NRUPPIP(L).EQ.1)THEN
60335           DO 113 II=FALNUM,1,-1
60340             IF(FALNUM1(II).EQ.(2010+L))THEN
60345               K=K+1
60350               CONLEAK(K)=II
60355               GO TO 102
60360             ENDIF
60365           113 CONTINUE
60370       ELSE
60375   RPPIVOL(L)=0
60380         ENDIF
60385     102 IF(NPIPLK(L).EQ.1)THEN
```

```
        DO 114 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.(3010+L))THEN
            K=K+1
            CONLEAK(K)=II
            GO TO 103
          ENDIF
        114 CONTINUE
    ELSE
PILKVOL(L)=0
      ENDIF
  103 IF(NGSKLK(L).EQ.1)THEN
        DO 115 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.(3050+L))THEN
            K=K+1
            CONLEAK(K)=II
            GO TO 104
          ENDIF
        115 CONTINUE
    ELSE
GKLKVOL(L)=0
      ENDIF
  104 IF(NWLDDEF(L).EQ.1)THEN
        DO 116 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.(1040+L))THEN
            K=K+1
            CONLEAK(K)=II
            GO TO 105
          ENDIF
        116 CONTINUE
    ELSE
WLDEFVL(L)=0
      ENDIF
  105 IF(NRUPWLD(L).EQ.1)THEN
        DO 117 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.(2040+L))THEN
            K=K+1
            CONLEAK(K)=II
            GO TO 106
          ENDIF
        117 CONTINUE
    ELSE
RPWLVOL(L)=0
      ENDIF
  106 IF(NGSKDEF(L).EQ.1)THEN
        DO 118 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.(1050+L))THEN
            K=K+1
            CONLEAK(K)=II
            GO TO 107
          ENDIF
        118 CONTINUE
    ELSE
GKDEFVL(L)=0
      ENDIF
  107 IF(NPMPLK(L).EQ.1)THEN
        DO 119 II=FALNUM,1,-1
          IF(FALNUM1(II).EQ.(3020+L))THEN
```

```
              K=K+1
              CONLEAK (K)=II
              GO TO 108
            ENDIF
          119 CONTINUE
          108 CONTINUE
      ELSE
  PMLKVOL (L)=0
        ENDIF
100 CONTINUE
DO 1000 L=1,NTK
        IF (NTNKDEF (L) .EQ.1) THEN
          DO 120 II=FALNUM,1,-1
            IF (FALNUM1 (II) .EQ.1030+L) THEN
              K=K+1
              CONLEAK (K)=II
              GO TO 109
            ENDIF
          120 CONTINUE
      ELSE
TKDEFVL (L)=0
        ENDIF
    109 IF (NTNKLK (L) .EQ.1) THEN
          DO 121 II=FALNUM,1,-1
            IF (FALNUM1 (II) .EQ.3030+L) THEN
              K=K+1
              CONLEAK (K)=II
              GO TO 434
            ENDIF
          121 CONTINUE
      ELSE
TKLKVOL (L)=0
        ENDIF
    434 IF (NRUPTNK (L) .EQ.1) THEN
          DO 122 II=FALNUM,1,-1
            IF (FALNUM1 (II) .EQ.2030+L) THEN
              K=K+1
              CONLEAK (K)=II
              GO TO 111
            ENDIF
          122 CONTINUE
          111 CONTINUE
      ELSE
RPTKVOL (L)=0
        ENDIF
1000 CONTINUE
  JJ=0
  DO 130 II=1,FALNUM
IF (K.NE.0) THEN
     DO 140 LL=1,K
       IF (II.EQ.CONLEAK (LL)) THEN
         JJ=JJ+1
         FALNUM1 (JJ)=FALNUM1 (CONLEAK (LL))
         FALNUM4 (JJ)=FALNUM4 (CONLEAK (LL))
      FALNUM2 (JJ)=FALNUM2 (II)
      VOL1=VOL1+FALNUM2 (II)
         GO TO 150
         ENDIF
       140 CONTINUE
       150 CONTINUE
        ENDIF
       FALNUM3(II)=0
       FALNUM7(II)=0
       FALNUM5(II)=0
    FALNUM6(II)='ND'
    IF(JJ.LT.II)THEN
      FALNUM1(II)=0
        FALNUM2(II)=0
      FALNUM4(II)=0
   ENDIF
    130 CONTINUE
   FALNUM=JJ
ENDIF
PIPMON=TPIPMON
MINV=EXMINV
WINVLIM=EXWINV
IINVLIM=EXIINV
TKTSTG=TTKTST
TNK1TST=TTK1TST
TNK5TST=TTK5TST
TNKSTST=TTKSTST
PITSTG=TPITST
PIP1TST=TPI1TST
PIP5TST=TPI5TST
PIPSTST=TPISTST
ULTRTST=TULTRTS
DO 65 II=1,6
    MONMETH(II)=TMNMETH(II)
65 CONTINUE
AGPOPUL=AGPOPUL+1
IF(FALNUM.NE.0)THEN
  DO 66 II=1,FALNUM
      IF(MOD(FALNUM1(II),100).EQ.30+L)THEN
        AGTKLK=AGTKLK+1
        GO TO 67
      ENDIF
  66 CONTINUE
  67 CONTINUE
ENDIF
RETURN
END
SUBROUTINE FIX(DLAB,MONTH,YR,L,FALTYP)
*    'FIX' REINITIALIZES THE VARIABLES ASSOCIATED WITH THE COMPONENTS
*  THAT ARE REPLACED.
COMMON/RETR/RETROFT
LOGICAL RETROFT
COMMON/CDIAM/PIDFDIA(5),PILKDIA(5),PMLKDIA(5),GKLKDIA(5),TKLKDIA
+(3)
REAL PIDFDIA,PILKDIA,PMLKDIA,GKLKDIA,TKLKDIA
COMMON/CRAD/CRADLE
LOGICAL CRADLE
      COMMON/AX/IY
COMMON/PIPELK/INTLK(5),PIPAGE(5),NUMLK(5),PRAN(5)
INTEGER INTLK,NUMLK,PIPAGE
```

```
61245 REAL PRAN
61250 COMMON/LOOPCT/NPI,NTK
61255 INTEGER NPI,NTK
61260 COMMON/IYRNO/IYRNUM
61265 COMMON/CONT/UGCONT(3),AGCONT(3),PIPCONT(5),NUGCONT(3),NAGCONT(3)
61270+,NPICONT(5)
61275 INTEGER UGCONT,AGCONT,PIPCONT,NUGCONT,NAGCONT,NPICONT
61280 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
61285 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
61290 INTEGER IYRNUM
61295 COMMON/THICKNS/PIPEI(5),PUMPI(5),GASKI(5)
61300 REAL PIPEI,PUMPI,GASKI,PDIAM,TKDIAM
61305 REAL PIPEE,PUMPE,GASKE,PIPE2E,PIPE2I
61310 COMMON/EXTHICK/PIPEE(5),PUMPE(5),GASKE(5),PIPE2E(5),PIPE2I(5)
61315 LOGICAL PIREPAR,TKREPAR,PMREPAR
61320 COMMON/PITRE/PIREPAR(5),TKREPAR(3),PMREPAR(5)
61325 COMMON/PIPETIM/PIPDEF(5),WLDDEF(5),GSKDEF(5),PIPLK(5),
61330+GSKLK(5),RUPPIP(5)
61335 COMMON/TANKTIM/TNKDEF(3),TNKLK(3),RUPTNK(3)
61340 COMMON/SURFTIM/LOOSE,HOSPORT,PMPLK(5),RUPWLD(5),VENT
61345 INTEGER PIPDEF,WLDDEF,GSKDEF,PIPLK,GSKLK,RUPPIP
61350 INTEGER TNKDEF,TNKLK,RUPTNK
61355 INTEGER LOOSE,HOSPORT,PMPLK,RUPWLD,VENT
61360 COMMON/DAVOL1/LOSEVOL,OVERVOL(12),HOSEVOL,PMLKVOL(5),RPWLVOL(5)
61365 REAL LOSEVOL,OVERVOL,HOSEVOL,PMLKVOL,RPWLVOL
61370 COMMON/VOL2/PIDEFVL(5),WLDEFVL(5),GKDEFVL(5),PILKVOL(5),GKLKVOL
61375+(5),RPPIVOL(5)
61380 REAL PIDEFVL,WLDEFVL,GKDEFVL,PILKVOL,GKLKVOL,RPPIVOL
61385 COMMON/VOL3/ TKDEFVL(3),TKLKVOL(3),RPTKVOL(3)
61390 REAL TKDEFVL,TKLKVOL,RPTKVOL
61395 COMMON/RATE1/ PIDEFRT(5),WLDEFRT(5),GKDEFRT(5),PILKRT(5),GKLKRT
61400+(5),RPPIRT(5)
61405 REAL PIDEFRT,WLDEFRT,GKDEFRT,PILKRT,GKLKRT,RPPIRT
61410 COMMON/RATE2/ TKDEFRT(3),TKLKRT(3),RPTKRT(3)
61415 COMMON/RATE3/ PMLKRT(5),RPWLRT(5)
61420 REAL TKDEFRT,TKLKRT,RPTKRT,PMLKRT,RPWLRT
61425 COMMON/BYPASS/WLDFLGR,WLDFLGD,GSKFLGL,GSKFLGD
61430 LOGICAL WLDFLGR,WLDFLGD,GSKFLGL,GSKFLGD
61435 LOGICAL TREMREP,PREMREP
61440 COMMON/REMREPS/TREMREP,PREMREP
61445 COMMON/VAPPRB/VAPSENS,VSENSOR
61450 REAL VAPSENS,VSENSOR
61455 INTEGER FALNUM,FALNUM1,FALNUM3,FALNUM4,FALNUM7
61460 COMMON/FALNUM/FALNUM,FALNUM1(100),FALNUM2(100),FALNUM3(100),
61465+  FALNUM4(100),FALNUM5(100),FALNUM7(100)
61470 COMMON/FALNUM6/FALNUM6(100)
61475 CHARACTER FALNUM6*2,DLAB*2
61480 REAL FALNUM2,FALNUM5
61485 REAL LYSIM,LYSDPTH,PLYSIM,TPNDPTH
61490 COMMON/LYS/LYSIM(2),LYSDPTH,PLYSIM
61495 COMMON/MCGDROP/MCWHORT,GDROP
61500 REAL MCWHORT,GDROP
61505 COMMON/CONTAM/PPNDPTH,TPNDPTH
61510 COMMON/DEFFLAG/DLTNK(3),DDTNK(3),DRTNK(3),DLGSK(5),DDGSK(5),
61515+DDWLD(5),DRWLD(5),DLPIP(5),DRPIP(5),DDPIP(5),DLPMP(5),DALL
61520 LOGICAL DLTNK,DDTNK,DRTNK,DLGSK,DDGSK,DDWLD,DRWLD,DLPIP,DRPIP,
61525+DDPIP,DLPMP,DALL
```

```
COMMON/THICK/TANKI(3),TANK2I(3)
COMMON/EXTHI/TANKE(3),TANK2E(3)
REAL TANKI,TANK2I
REAL TANKE,TANK2E
COMMON/ITHICK/IPIPE(5),IPUMP(5),ITANK(3),IGASK(5),ITANK2(3)
REAL IPIPE,IPUMP,ITANK,IGASK,ITANK2
REAL PPNDPTH
INTEGER YR,FALTYP,L,MONTH,IITYP
  DO 475 II=1,FALNUM
IF((FALNUM3(II).EQ.((YR-1)*12+MONTH)).AND.(FALNUM4(II).EQ.0))THEN
       IITYP=INT(MOD(FALNUM1(II),1000)/10)
      LL=MOD(FALNUM1(II),10)
       IF((IITYP.EQ.3).OR.
+(IITYP.EQ.7).OR.(IITYP.EQ.8).OR.(IITYP.EQ.9).OR.(IITYP
+.EQ.10))THEN
IF(AGTANK.AND.(IITYP.EQ.3))THEN
 IF((AGCONT(LL).EQ.MONTH).OR.(.NOT.CRADLE))THEN
    FALNUM4(II)=1
 ENDIF
ENDIF
IF(AGTANK.AND.(.NOT.(IITYP.EQ.3)))THEN
 IF((AGCONT(LL).EQ.MONTH))THEN
    FALNUM4(II)=1
 ENDIF
ENDIF
IF(IITYP.EQ.3)THEN
  IF(IGTANK.AND.(UGCONT(LL).EQ.MONTH))FALNUM4(II)=1
 ELSE
  IF(IGTANK.AND.(AGCONT(LL).EQ.MONTH))FALNUM4(II)=1
 ENDIF
  IF(UGTANK.AND.(UGCONT(LL).EQ.MONTH))FALNUM4(II)=1
      ELSEIF((IITYP.EQ.5).OR.(IITYP.EQ.4))THEN
IF(AGTANK.AND.((PIPCONT(L)
+  .EQ.MONTH)))FALNUM4(II)=1
IF(IGTANK.AND.(PIPCONT(L)
+.EQ.MONTH))FALNUM4(II)=1
 IF(UGTANK.AND.(UGCONT(LL-1+1/LL-LL/5)
+.EQ.MONTH))FALNUM4(II)=1
      ELSEIF(IITYP.EQ.1)THEN
         IF(PIPCONT(LL).EQ.MONTH)FALNUM4(II)=1
      ELSEIF((IITYP.EQ.2).OR.(IITYP.EQ.11))THEN
IF(AGPUMP.AND.(PIPCONT(L)
+.EQ.MONTH))FALNUM4(II)=1
      ELSE
         FALNUM4(II)=1
      ENDIF
   ENDIF
  475 CONTINUE
IF(FALTYP.EQ.1)IREMCH=3030+L
IF(FALTYP.EQ.2)IREMCH=2030+L
IF(FALTYP.EQ.3)IREMCH=1030+L
IF(FALTYP.EQ.4)IREMCH=3010+L
IF(FALTYP.EQ.5)IREMCH=2010+L
IF(FALTYP.EQ.6)IREMCH=1010+L
IF(FALTYP.EQ.7)IREMCH=1040+L
IF(FALTYP.EQ.8)IREMCH=1050+L
IF(FALTYP.EQ.9)IREMCH=3050+L
IF(FALTYP.EQ.10) IREMCH=2040+L
DO 311 NUMERAL=FALNUM,1,-1
    IF(FALNUM1(NUMERAL).EQ.IREMCH) THEN
       IF((FALNUM3(NUMERAL).EQ.((MONTH-1)+(YR-1)*12)).AND.(FALNUM6
          (NUMERAL).EQ.'ND')) FALNUM3(NUMERAL)=MONTH+(YR-1)*12
                 GO TO 312
       ENDIF
 311 CONTINUE
  312   CONTINUE
IF(NUMERAL.NE.0) THEN
   IF(FALNUM3(NUMERAL).EQ.(MONTH+(YR-1)*12)) FALNUM6(NUMERAL)=DLAB
ENDIF
IF(FALTYP.EQ.1) THEN
      TNKLK(L)=0
      TKLKRT(L)=0
        TKLKVOL(L)=0
     WLDFLGR=.FALSE.
     WLDFLGD=.FALSE.
     GSKFLGL=.FALSE.
     GSKFLGD=.FALSE.
        CALL INTREPL(3,L)
        CALL EXTREPL(L,3)
      IF(.NOT.TKREPAR(L)) THEN
          CALL REPLAC(3,1)
VAPSENS=VSENSOR
          LYSIM(1)=PLYSIM
             GDROP=0
           IF(NUMERAL.GT.0.) THEN
          IF(FALNUM4(NUMERAL).EQ.1) TREMREP=.TRUE.
           ENDIF
           DLTNK(L)=.TRUE.
          TKREPAR(L)=.TRUE.
           TANKI(L)=ITANK(L)
           TANKE(L)=ITANK(L)
         TANK2I(L)=ITANK(L)
          TANK2E(L)=ITANK(L)
      ENDIF
ELSEIF(FALTYP.EQ.2) THEN
      RUPTNK(L)=0
      RPTKRT(L)=0
      RPTKVOL(L)=0
     WLDFLGR=.FALSE.
     WLDFLGD=.FALSE.
     GSKFLGL=.FALSE.
     GSKFLGD=.FALSE.
        CALL INTREPL(3,L)
        CALL EXTREPL(L,3)
      IF(.NOT.TKREPAR(L)) THEN
          CALL REPLAC(3,1)
VAPSENS=VSENSOR
          LYSIM(1)=PLYSIM
             GDROP=0
           DRTNK(L)=.TRUE.
           IF(NUMERAL.GT.0.) THEN
          IF(FALNUM4(NUMERAL).EQ.1) TREMREP=.TRUE.
           ENDIF
          TKREPAR(L)=.TRUE.
          TANKI(L)=ITANK(L)
          TANKE(L)=ITANK(L)
        TANK2I(L)=ITANK(L)
         TANK2E(L)=ITANK(L)
      ENDIF
ELSEIF(FALTYP.EQ.3)THEN
      TNKDEF(L)=0
      TKDEFRT(L)=0
       TKDEFVL(L)=0.
    WLDFLGR=.FALSE.
    WLDFLGD=.FALSE.
    GSKFLGL=.FALSE.
    GSKFLGD=.FALSE.
       CALL INTREPL(3,L)
       CALL EXTREPL(L,3)
      IF(.NOT.TKREPAR(L))THEN
         CALL REPLAC(3,1)
VAPSENS=VSENSOR
         LYSIM(1)=PLYSIM
            GDROP=0
          DDTNK(L)=.TRUE.
          IF(NUMERAL.GT.0.)THEN
         IF(FALNUM4(NUMERAL).EQ.1)TREMREP=.TRUE.
          ENDIF
         TKREPAR(L)=.TRUE.
          TANKI(L)=ITANK(L)
          TANKE(L)=ITANK(L)
        TANK2I(L)=ITANK(L)
         TANK2E(L)=ITANK(L)
      ENDIF
ELSEIF(FALTYP.EQ.4)THEN
      PIPLK(L)=0
      INTLK(L)=0
      PIPAGE(L)=0
      NUMLK(L)=0
      PRAN(L)=FNU(0.,2.)
      PILKRT(L)=0
      PILKVOL(L)=0
    WLDFLGR=.FALSE.
    WLDFLGD=.FALSE.
    GSKFLGL=.FALSE.
    GSKFLGD=.FALSE.
      CALL INTREPL(1,L)
      CALL EXTREPL(L,1)
         IF(.NOT.PIREPAR(L)) THEN
         CALL REPLAC(1,L)
         DLPIP(L)=.TRUE.
         IF(NUMERAL.GT.0.)THEN
        IF(FALNUM4(NUMERAL).EQ.1)PREMREP=.TRUE.
         ENDIF
         PIREPAR(L)=.TRUE.
         PIPEI(L)=IPIPE(L)
         PIPEE(L)=IPIPE(L)
   PIPE2E(L)=IPIPE(L)
   PIPE2I(L)=IPIPE(L)
         GASKI(L)=IGASK(L)
          GASKE(L)=IGASK(L)
          ENDIF
       PILKDIA(L)=0.
ELSEIF(FALTYP.EQ.5)THEN
     RUPPIP(L)=0
       INTLK(L)=0
      PIPAGE(L)=0
      NUMLK(L)=0
      PRAN(L)=FNU(0.,2.)
     RPPIVOL(L)=0
   RPPIRT(L)=0
    WLDFLGR=.FALSE.
    WLDFLGD=.FALSE.
    GSKFLGL=.FALSE.
    GSKFLGD=.FALSE.
      CALL INTREPL(1,L)
      CALL EXTREPL(L,1)
          IF(.NOT.PIREPAR(L))  THEN
          CALL REPLAC(1,L)
          DRPIP(L)=.TRUE.
          IF(NUMERAL.GT.0.)THEN
         IF(FALNUM4(NUMERAL).EQ.1)PREMREP=.TRUE.
          ENDIF
          PIREPAR(L)=.TRUE.
          PIPEI(L)=IPIPE(L)
          PIPEE(L)=IPIPE(L)
   PIPE2E(L)=IPIPE(L)
   PIPE2I(L)=IPIPE(L)
          GASKI(L)=IGASK(L)
           GASKE(L)=IGASK(L)
          ENDIF
      PILKDIA(L)=0.
ELSEIF(FALTYP.EQ.6)THEN
     PIPDEF(L)=0
       INTLK(L)=0
      PIPAGE(L)=0
      NUMLK(L)=0
      PRAN(L)=FNU(0.,2.)
     PIDEFVL(L)=0
   PIDEFRT(L)=0
    WLDFLGR=.FALSE.
    WLDFLGD=.FALSE.
    GSKFLGL=.FALSE.
    GSKFLGD=.FALSE.
      CALL INTREPL(1,L)
      CALL EXTREPL(L,1)
          IF(.NOT.PIREPAR(L))  THEN
          CALL REPLAC(1,L)
          DDPIP(L)=.TRUE.
          IF(NUMERAL.GT.0.)THEN
         IF(FALNUM4(NUMERAL).EQ.1)PREMREP=.TRUE.
          ENDIF
          PIREPAR(L)=.TRUE.
          PIPEI(L)=IPIPE(L)
          PIPEE(L)=IPIPE(L)
   PIPE2E(L)=IPIPE(L)
   PIPE2I(L)=IPIPE(L)
          GASKI(L)=IGASK(L)
          GASKE (L) =IGASK (L)
         ENDIF
      PILKDIA (L) =0.
ELSEIF (FALTYP.EQ.7) THEN
        WLDDEF (L) =0
        WLDEFVL (L) =0
        WLDEFRT (L) =0
    WLDFLGR=.FALSE.
    WLDFLGD=.FALSE.
IF (.NOT. (PIREPAR (L) .OR.TKREPAR (L-1+1/L-L/5)))
+THEN
               PIREPAR (L) =.TRUE.
        GDROP=0
         DDWLD (L) =.TRUE.
         IF (NUMERAL.GT.0.) THEN
        IF (FALNUM4 (NUMERAL) .EQ.1) TREMREP=.TRUE.
         ENDIF
        ENDIF
ELSEIF (FALTYP.EQ.8) THEN
      GSKDEF (L) =0
      GKDEFRT (L) =0
      GKDEFVL (L) =0
    GSKFLGL=.FALSE.
    GSKFLGD=.FALSE.
IF (.NOT. (PIREPAR (L) .OR.TKREPAR (L-1+1/L-L/5)))
+THEN
            PIREPAR (L) =.TRUE.
        GDROP=0
         DDGSK (L) =.TRUE.
         IF (NUMERAL.GT.0.) THEN
        IF (FALNUM4 (NUMERAL) .EQ.1) TREMREP=.TRUE.
         ENDIF
         GASKI (L) =IGASK (L)
          GASKE (L) =IGASK (L)
     ENDIF
ELSEIF (FALTYP.EQ.9) THEN
        GKLKVOL (L) =0
        GSKLK (L) =0
        GKLKRT (L) =0
    GSKFLGL=.FALSE.
    GSKFLGD=.FALSE.
IF (.NOT. (PIREPAR (L) .OR.TKREPAR (L-1+1/L-L/5)))
+THEN
          PIREPAR (L) =.TRUE.
        GDROP=0
         DLGSK (L) =.TRUE.
         IF (NUMERAL.GT.0.) THEN
        IF (FALNUM4 (NUMERAL) .EQ.1) TREMREP=.TRUE.
         ENDIF
         GASKI (L) =IGASK (L)
          GASKE (L) =IGASK (L)
     ENDIF
ELSE
              RPWLVOL (L) =0
            RPWLRT (L) =0
              RUPWLD (L) =0
    WLDFLGR=.FALSE.
```

```
62955      WLDFLGD=.FALSE.
62960 IF(.NOT.(PIREPAR(L).OR.TKREPAR(L-1+1/L-L/5)))
62965+THEN
62970           PIREPAR(L)=.TRUE.
62975         GDROP=0
62980          DRWLD(L)=.TRUE.
62985          IF(NUMERAL.GT.0.)THEN
62990         IF(FALNUM4(NUMERAL).EQ.1)TREMREP=.TRUE.
62995          ENDIF
63000         ENDIF
63005 ENDIF
63010 RETURN
63015 END
63020 SUBROUTINE VAPZERO(COMP,L)
63025*  'VAPZERO' RESETS THE VARIABLES ASSOCIATED WITH VAPOR WELLS WHEN A
63030* COMPONENT IS REPLACED.
63035 COMMON/VAPOR/TKDFVAP,TKRPVAP,TKLKVAP,PIDFVAP(5),PIRPVAP(5),
63040+ PILKVAP(5),WGDFVAP(5),WGLRVAP(5),PMPVAP(5)
63045 REAL TKDFVAP,TKRPVAP,TKLKVAP,PIDFVAP,PIRPVAP,PILKVAP,
63050+     WGDFVAP,WGLRVAP,PMPVAP
63055 COMMON/VFLAG/VAPFLG,VAPDET
63060 LOGICAL VAPFLG,VAPDET
63065 INTEGER COMP,L
63070 IF(COMP.EQ.1)THEN
63075     PIRPVAP(L)=0
63080     PIDFVAP(L)=0
63085     PILKVAP(L)=0
63090     WGDFVAP(L)=0
63095     WGLRVAP(L)=0
63100    ELSEIF(COMP.EQ.3)THEN
63105     TKLKVAP=0
63110     TKRPVAP=0
63115     TKDFVAP=0
63120     VAPFLG=.FALSE.
63125     DO 232 M=1,2
63130     WGLRVAP(L)=0
63135     WGDFVAP(L)=0
63140     232 CONTINUE
63145    ELSE
63150     WGLRVAP(L)=0
63155     WGDFVAP(L)=0
63160 ENDIF
63165 RETURN
63170 END
63175 SUBROUTINE DETDIST(TIME)
63180*  THIS ROUTINE CREATES THE RELEASE INCIDENT DETECTION TIME
63185*  DISTRIBUTION.
63190* TIME IS IN HOURS
63195 COMMON/DTDIST/DETSIZE(12)
63200 INTEGER DETSIZE
63205 INTEGER TIME
63210 IF(TIME.LE.24)THEN
63215     DETSIZE(1)=DETSIZE(1)+1
63220 ELSEIF(TIME.LE.148)THEN
63225     DETSIZE(2)=DETSIZE(2)+1
63230 ELSEIF(TIME.LE.720)THEN
63235     DETSIZE(3)=DETSIZE(3)+1
```

```
63240 ELSEIF(TIME.LE.4380)THEN
63245     DETSIZE(4)=DETSIZE(4)+1
63250 ELSEIF(TIME.LE.8760)THEN
63255     DETSIZE(5)=DETSIZE(5)+1
63260 ELSEIF(REAL(TIME/8760.).LE.3)THEN
63265     DETSIZE(6)=DETSIZE(6)+1
63270 ELSEIF(REAL(TIME/8760.).LE.5)THEN
63275     DETSIZE(7)=DETSIZE(7)+1
63280 ELSEIF(REAL(TIME/8760.).LE.10)THEN
63285     DETSIZE(8)=DETSIZE(8)+1
63290 ELSEIF(REAL(TIME/8760.).LE.15)THEN
63295     DETSIZE(9)=DETSIZE(9)+1
63300 ELSEIF(REAL(TIME/8760.).LE.20)THEN
63305     DETSIZE(10)=DETSIZE(10)+1
63310 ELSEIF(REAL(TIME/8760.).LE.25)THEN
63315     DETSIZE(11)=DETSIZE(11)+1
63320 ELSE
63325     DETSIZE(12)=DETSIZE(12)+1
63330 ENDIF
63335 RETURN
63340 END
63345 SUBROUTINE COATS(COMP,LOC)
63350*   'COATS' SETS THE COATING TIME OF FAILURE.
63355 COMMON/CRAD/CRADLE
63360 LOGICAL CRADLE
63365 COMMON/IYRNO/IYRNUM
63370 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
63375 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
63380 COMMON/COAT/COATING(4,3,5)
63385 LOGICAL COATING
63390 COMMON/COATIM/ICOATIM(3,5),ECOATIM(3,5)
63395 REAL ICOATIM,ECOATIM
63400 INTEGER IYRNUM,COMP,LOC
63405 IF(COMP.EQ.3)THEN
63410     IF(COATING(3,COMP,1))THEN
63415        ICOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63420        IF(AGTANK.AND.CRADLE)THEN
63425           ECOATIM(COMP,LOC)=FNN(9.,3.)+IYRNUM
63430          ELSE
63435           ECOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63440        ENDIF
63445       ELSEIF(COATING(1,COMP,1))THEN
63450        ICOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63455        ECOATIM(COMP,LOC)=0.
63460       ELSEIF(COATING(2,COMP,1))THEN
63465        ICOATIM(COMP,LOC)=0.
63470        IF(AGTANK.AND.CRADLE)THEN
63475           ECOATIM(COMP,LOC)=FNN(9.,3.)+IYRNUM
63480          ELSE
63485           ECOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63490         ENDIF
63495        ELSE
63500*      NO COATING
63505         ICOATIM(COMP,LOC)=0.
63510         ECOATIM(COMP,LOC)=0.
63515     ENDIF
63520  ELSEIF(COMP.EQ.1)THEN
```

```
63525     IF(COATING(3,COMP,1))THEN
63530       ICOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63535       IF(AGPIPE)THEN
63540          ECOATIM(COMP,LOC)=FNN(9.,3.)+IYRNUM
63545         ELSE
63550          ECOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63555       ENDIF
63560      ELSEIF(COATING(1,COMP,1))THEN
63565       ICOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63570       ECOATIM(COMP,LOC)=0.
63575      ELSEIF(COATING(2,COMP,1))THEN
63580       ICOATIM(COMP,LOC)=0.
63585       IF(AGPIPE)THEN
63590          ECOATIM(COMP,LOC)=FNN(9.,3.)+IYRNUM
63595         ELSE
63600          ECOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63605        ENDIF
63610       ELSE
63615*     NO COATING
63620        ICOATIM(COMP,LOC)=0.
63625        ECOATIM(COMP,LOC)=0.
63630     ENDIF
63635   ELSEIF(COMP.EQ.2)THEN
63640    IF(COATING(3,COMP,1))THEN
63645       ICOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63650       IF(AGPUMP)THEN
63655          ECOATIM(COMP,LOC)=FNN(9.,3.)+IYRNUM
63660         ELSE
63665          ECOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63670       ENDIF
63675      ELSEIF(COATING(1,COMP,1))THEN
63680       ICOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63685       ECOATIM(COMP,LOC)=0.
63690      ELSEIF(COATING(2,COMP,1))THEN
63695       ICOATIM(COMP,LOC)=0.
63700       IF(AGPUMP)THEN
63705          ECOATIM(COMP,LOC)=FNN(9.,3.)+IYRNUM
63710         ELSE
63715          ECOATIM(COMP,LOC)=FNN(7.,3.)+IYRNUM
63720        ENDIF
63725       ELSE
63730*     NO COATING
63735        ICOATIM(COMP,LOC)=0.
63740        ECOATIM(COMP,LOC)=0.
63745     ENDIF
63750   ELSE
63755*     REPLACE EVERYTHING (COMP=8)
63760    DO 44445 KK=1,3
63765       DO 44444 I=1,5
63770    IF(ICOATIM(KK,I).GT.0.)  ICOATIM(KK,I)=ICOATIM(KK,I)+IYRNUM
63775    IF(ECOATIM(KK,I).GT.0.)  ECOATIM(KK,I)=ECOATIM(KK,I)+IYRNUM
63780       44444 CONTINUE
63785     44445 CONTINUE
63790  ENDIF
63795 RETURN
63800 END
63805 SUBROUTINE SECCON(TYPE,THICK,MAINT,GENYR)
```

```
*   THIS SUBROUTINE CALCULATES THE DATES OF GENERAL A
* FAILURE FOR VARIOUS SECONDARY CONTAINMENT DEVICES.  TYPE: SPECIFIES
*  THE  TYPE  OF SECONDARY CONTAINMENT; THICK: GIVES THE THICKNESS OF
THE
* SLAB;
*  GENYR: GIVES THE DATE OF GENERALIZED BREAKUP; MAINT: IS A
* LOGICAL VARIABLE INDICATING WHETHER OR NOT MAINTENANCE OCCURS.
*
REAL THICK,GENYR
INTEGER TYPE
LOGICAL MAINT
*
* ASPHALT PAD
IF(TYPE.EQ.1) GO TO 100
* ASPHALT BERM
IF(TYPE.EQ.2) GO TO 100
* CONCRETE PAD
IF(TYPE.EQ.3) GO TO 200
* CONCRETE BERM
IF(TYPE.EQ.4) GO TO 300
* VAULT
IF(TYPE.EQ.5) GO TO 400
*
100 IF((THICK.LE.2.5).AND.(.NOT.MAINT))THEN
      GENYR=FNBE(8.,2.5,12.)
    ELSEIF((THICK.LE.2.5).AND.MAINT)THEN
      GENYR=FNBE(12.,4.,15.)
    ELSEIF((THICK.GT.2.5).AND.(.NOT.MAINT))THEN
      GENYR=FNBE(12.,4.,15.)
    ELSE
      GENYR=FNBE(15.,5.,18.)
    ENDIF
    GO TO 1000
200 GENYR=FNN(30.,5.)
    GO TO 1000
300 GENYR=FNN(30.,5.)
    GO TO 1000
400 GENYR=FNN(35.,10.)
1000 RETURN
    END
SUBROUTINE LKPIPE(AGE,AREA,Z,N,RANDOM,FLAG,CFLAG)
COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK;AGPIPE,AGPUMP
LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
COMMON/SOIL/SATSOIL,SPH,RESIS,SULFSOL
 REAL RESIS,SPH,AREA
LOGICAL BAKFILL
COMMON/BAKFILL/BAKFILL(4)
*THIS SUBROUTINE DETERMINES WHETHER OR NOT A LEAK HAS OCCURRED
*GIVEN THE FOLLOWING VARIABLES.
*AGE (AGE OF PIPE SEGMENT)
* AREA (SURFACE AREA OF THE PIPE)
* SPH
* RESIS (RESISTIVITY)
* Z (THICKNESS OF THE PIPE AFTER ALLOWANCES FOR GENERALIZED
* INTERIOR CORROSION AND EROSION)
* N (THE NUMBER OF PREVIOUS LEAKS IN THIS PARTICULAR PIPE SEG.)
* RANDOM (A RANDOM NUMBER WHICH IS ONLY CHANGED IF A LEAK OCCURS)
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64090* FLAG IS THE OUTPUT VARIABLE
64095* CFLAG INDICATES IF COATING HAS FAILED
64100 INTEGER N
64105 REAL AGE
64110 REAL RANDOM,Z
64115 LOGICAL FLAG,CFLAG
64120 REAL KN,XN
64125 IF(BAKFILL(1))THEN
64130    KN=355.
64135    XN=0.50
64140 ELSEIF(BAKFILL(2).OR.BAKFILL(3))THEN
64145    KN=222.
64150    XN=.333
64155 ELSE
64160    KN=170.
64165    XN=.16667
64170 ENDIF
64175* Z MUST BE CONVERTED TO MILS
64180*IF(UGPIPE)THEN
64185 IF(CFLAG)THEN
64190 XL=((AREA*(KN*1.06/(Z*1000.))**(6.25)*(AGE*(10-SPH)/RESIS)**
64195+(XN/0.16)))*2-N
64200 CFLAG=.FALSE.
64205 ELSE
64210 XL=(AREA*(KN*1.06/(Z*1000.))**(6.25)*(AGE*(10-SPH)/RESIS)**
64215+(XN/0.16))-N
64220 ENDIF
64225*ELSE
64230*   AGPIPE
64235*IF(CFLAG)THEN
64240*XL=((.05*AREA*(222.*1.06/(Z*1000.))**(6.25)*(AGE*(10-6.)/15000.)**
64245*(.333/0.16)))*2-N
64250*CFLAG=.FALSE.
64255*ELSE
64260*XL=(.05*AREA*(222.*1.06/(Z*1000.))**(6.25)*(AGE*(10-6.)/15000.)**
64265*(.333/0.16))-N
64270*ENDIF
64275*ENDIF
64280* XL IS THE EXPECTED CUMULATIVE NUMBER OF LEAKS.  IT IS
64285* BASED ON A MODEL BY ROSSUM.
64290* THIS MODIFICATION IS MADE TO FOCUS ATTENTION UPON THE NEXT LEAK.
64295 IF(RANDOM.LE.XL)THEN
64300    FLAG=.TRUE.
64305 ELSE
64310    FLAG=.FALSE.
64315 ENDIF
64320 RETURN
64325 END
64330 SUBROUTINE INTREPL(COMP,I)
64335*   THIS ROUTINE RESAMPLES THE PROBABILITY OF INTERIOR
64340* LOCALIZED CORROSION FOR A COMPONENT THAT WAS REPLACED.
64345 COMMON/AREAS2/PIPESA(5)
64350 REAL PIPESA
64355 REAL TANKSA
64360 COMMON/AREAS/TANKSA(3)
64365 INTEGER COMP
64370 COMMON/LOOPCT/NPI,NTK
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```
 INTEGER NPI,NTK
 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP

 COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
 LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
 COMMON/CORE/PCORE(5),GCORE(5),PMCORE(5),TCORE(3),TCORE2(3)
 COMMON/CORE1/PCORE2(5),PIEXT2(5),PIEXLO2(5)
 REAL PCORE2,PIEXT2,PIEXLO2
 COMMON/LIFCOR/LIFCOR(2,5)
 COMMON/ITHICK/IPIPE(5),IPUMP(5),ITANK(3),IGASK(5),ITANK2(3)
 REAL IPIPE,IPUMP,ITANK,IGASK,ITANK2
 COMMON/ILOCAL/PILOCAL(5),PMLOCAL(5),TKLOCAL(3),TKLOCA2(3)
 REAL PILOCAL,PMLOCAL,TKLOCAL,TKLOCA2
 REAL PCORE,GCORE,PMCORE,TCORE,TCORE2
 REAL LIFCOR
 REAL PIPLOC(5),PMPLOC(5),TNKLOC(3)
 REAL THADJ
 COMMON/MATPAR/APAR,CPAR,APARPI,CPARPI,APARPM,CPARPM
 REAL APAR,CPAR,APARPI,CPARPI,APARPM,CPARPM
 COMMON/VENT/VCORE,VENTI,VENTE,IVENT,VLOCAL,VNTLOC,VEXT,
+VEXTLOC
 REAL VNTLOC
 REAL VCORE,VENTI,VENTE,IVENT,VLOCAL,VEXT,VEXTLOC
 INTEGER I

 IF(COMP.EQ.6)THEN
 VLOCAL=0.
     VNTLOC=FNB(LIFCOR(1,5))
     IF(VNTLOC.EQ.1)THEN
        THADJ=IVENT/.25
        VLOCAL=(IVENT/FNN(8.*APARPI*THADJ,5*APARPI))-VCORE
        IF(VLOCAL.LT.O)VLOCAL=0.
     ENDIF
 ENDIF
 IF(COMP.EQ.1)THEN
 PILOCAL(I)=0.
     PIPLOC(I)=FNB(LIFCOR(1,5)*((PIPESA(I)/10.47)**.16))
     IF(PIPLOC(I).EQ.1)THEN
        THADJ=IPIPE(I)/.25
     PILOCAL(I)=((IPIPE(I)/FNN(8.*APARPI*THADJ,5*APARPI))-PCORE(I)
+   )*((PIPESA(I)/10.47)**.16)
        IF(PILOCAL(I).LT.O.)PILOCAL(I)=0.
     ENDIF
 ENDIF
 IF(COMP.EQ.2)THEN
 PMLOCAL(I)=0.
 IF(AGPUMP) THEN
     PMPLOC(I)=FNB(LIFCOR(1,5))
     IF(PMPLOC(I).EQ.1)THEN
        THADJ=IPUMP(I)/.25
    PMLOCAL(I)=(IPUMP(I)/FNN(8.*APARPM*THADJ,5*APARPM))-PMCORE(I)
        IF(PMLOCAL(I).LT.O.)PMLOCAL(I)=0.
     ENDIF
 ENDIF
 ENDIF
 IF(COMP.EQ.3)THEN
```

```
64660 TKLOCAL(I)=0.
64665 TKLOCA2(I)=0.
64670       TNKLOC(I)=FNB(LIFCOR(1,1))
64675       IF(TNKLOC(I).EQ.1)THEN
64680          THADJ=ITANK(I)/.25
64685       TKLOCAL(I)=(ITANK(I)/FNN(8.*APAR,5.*APAR))-TCORE(I)
64690       IF((TKLOCAL(I).LT.0.).OR.FRP)TKLOCAL(I)=0.
64695       ENDIF
64700 ENDIF
64705 RETURN
64710 END
64715 SUBROUTINE EXTREPL(I,COMP)
64720*   THIS ROUTINE RESAMPLES THE EXTERIOR CORROSION RATE
64725*  FOR THE COMPONENT THAT WAS REPLACED.
64730 REAL TANKSA
64735 COMMON/AREAS/TANKSA(3)
64740 INTEGER I,COMP
64745 COMMON/AREAS2/PIPESA(5)
64750 REAL PIPESA
64755 COMMON/PIFRP/PFRP
64760 LOGICAL PFRP
64765 COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
64770 LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
64775 COMMON/MATL/TNKMATL,PIPMATL
64780 COMMON/ELOCAL/PIEXLOC(5),TKEXLOC(3),TKEXLO2(3)
64785 REAL PIEXLOC,TKEXLOC,TKEXLO2
64790 COMMON/EXTERN/EXCORLO
64795 COMMON/CORE1/PCORE2(5),PIEXT2(5),PIEXLO2(5)
64800 REAL PCORE2,PIEXT2,PIEXLO2
64805 INTEGER TNKMATL,PIPMATL
64810 REAL EXCORLO
64815 COMMON/WALL/TK2WALL,PI2WALL
64820 LOGICAL TK2WALL,PI2WALL
64825 COMMON/PLACE/UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
64830 LOGICAL UGPIPE,AGTANK,IGTANK,UGTANK,AGPIPE,AGPUMP
64835 COMMON/ECORE/PIEXT(5),TKEXT(3),PMEXT(5),TKEXT2(3)
64840 REAL PIEXT,TKEXT,PMEXT,TKEXT2
64845 IF(COMP.EQ.1)THEN
64850    IF(.NOT.PFRP)THEN
64855       PIEXT(I)=EXTCOR(I,PIPMATL,1,.19)
64860     PIEXLOC(I)=EXCORLO*(PIPESA(I)/10.47)**.16
64865    ELSE
64870    PIEXT(I)=0.
64875    PIEXLOC(I)=0.
64880    ENDIF
64885 IF(PI2WALL)THEN
64890    IF(.NOT.PFRP)THEN
64895       PIEXT2(I)=PIEXT(I)
64900       PIEXT(I)=0.
64905       PIEXLO2(I)=PIEXLOC(I)
64910       PIEXLOC(I)=0.
64915    ELSE
64920       PIEXT2(I)=0.
64925       PIEXLO2(I)=0.
64930       PIEXT(I)=0.
64935       PIEXLOC(I)=0.
64940    ENDIF
```

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ENDIF
ENDIF
IF(COMP.EQ.3)THEN
      IF(.NOT.(FRP.OR.CONCRT))THEN
         TKEXT(I)=EXTCOR(I,TNKMATL,3,.25)
         TKEXLOC(I)=EXCORLO*(TANKSA(I)/446.)**.16
         ELSE
         TKEXT(I)=0.
         TKEXLOC(I)=0.
         ENDIF
   IF(TK2WALL)THEN
   IF(.NOT.(FRP.OR.CONCRT))THEN
         TKEXT2(I)=EXTCOR(I,TNKMATL,3,.25)
         TKEXLO2(I)=EXCORLO
         TKEXT(I)=0
         TKEXLOC(I)=0
   ELSE
   TKEXT2(I)=0.
   TKEXLO2(I)=0.
   TKEXT(I)=0.
   TKEXLOC(I)=0.
   ENDIF
   ENDIF
ENDIF
RETURN
END
SUBROUTINE VOLADJ(TEMPVOL,YRVOL,COMP,STAGE,CALCVOL)
* FOR TREATMENT PROCESSES THE RELEASE VOLUMES HAVE TO BE
* ADJUSTED SO THAT THEY ONLY REFLECT THE AMOUNT OF UNTREATED
* WASTE THAT HAS BEEN RELEASED.
COMMON/TECH/NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP,STORAGE,ACTCARB
LOGICAL BATCH,CONT,PCSTEEL,
+PSSTEEL,IGWASTE,AUTSHUT,NEUT,CHRED,CYNOX,PRECIP,DISTILL,EVAP
+,STORAGE,ACTCARB
COMMON/EFFIC/TRTEFF,DVOLFR
REAL TRTEFF,DVOLFR
REAL TEMPVOL,YRVOL,CALCVOL
INTEGER COMP,STAGE
IF(STAGE.EQ.0)THEN
 IF(DISTILL)THEN
   IF(COMP.EQ.6)THEN
   CALCVOL=CALCVOL+YRVOL*.5*DVOLFR+YRVOL*.5
   ELSE
   CALCVOL=CALCVOL+YRVOL
   ENDIF
  ELSE
  IF(COMP.EQ.6)THEN
   CALCVOL=CALCVOL+YRVOL*(.5/6.5)+YRVOL*(6/6.5)*(1-TRTEFF)
   ELSE
  CALCVOL=CALCVOL+YRVOL*(1-TRTEFF)
   ENDIF
  ENDIF
ELSEIF(STAGE.EQ.1)THEN
  IF(DISTILL)THEN
   CALCVOL=CALCVOL+YRVOL*DVOLFR
  ELSE
  CALCVOL=CALCVOL+YRVOL
```

```
   ENDIF
ELSEIF(STAGE.EQ.2)THEN
  IF(DISTILL)THEN
      CALCVOL=CALCVOL+YRVOL
  ELSE
    IF(COMP.EQ.3)THEN
      CALCVOL=CALCVOL+YRVOL*(1-TRTEFF)
    ELSE
      CALCVOL=CALCVOL+YRVOL
    ENDIF
  ENDIF
ELSEIF(STAGE.EQ.3)THEN
  IF(DISTILL)THEN
         CALCVOL=CALCVOL+YRVOL
  ELSE
    CALCVOL=CALCVOL+YRVOL*(1-TRTEFF)
  ENDIF
ELSEIF(STAGE.EQ.4)THEN
  IF(DISTILL)THEN
         CALCVOL=CALCVOL+YRVOL*((1-TRTEFF)/(1+(1-TRTEFF)))
  ELSE
    CALCVOL=CALCVOL+YRVOL*(1-TRTEFF)
  ENDIF
ELSE
  IF(CYNOX.OR.CHRED.OR.PRECIP)THEN
    CALCVOL=CALCVOL+YRVOL*(1-TRTEFF)
  ELSE
  ENDIF
ENDIF
TEMPVOL=TEMPVOL-YRVOL
RETURN
END
SUBROUTINE RETRO
*   'RETRO' INITIALIZES THE VARIABLES USED IN THE RETROFITTED
*  CONTAINMENT OPTION THAT WAS SELECTED.
COMMON/TANKMAT/CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
LOGICAL CSTEEL,SSTEEL,FRP,CATSTEL,PICATH,CONCRT
REAL CATTIM
COMMON/CATSYS/CATTIM
COMMON/CONT/UGCONT(3),AGCONT(3),PIPCONT(5),NUGCONT(3),NAGCONT(3)
+,NPICONT(5)
INTEGER UGCONT,AGCONT,PIPCONT,NUGCONT,NAGCONT,NPICONT
COMMON/RETR/RETROFT
LOGICAL RETROFT
COMMON/LOOPCT/NPI,NTK
INTEGER NPI,NTK
COMMON/LINE/LINETIM(3)
REAL LINETIM
COMMON/TIME/APADTIM(3),CPADTIM(3),VLTTIM(3),CBRMTIM(3),ABRMTIM(3)
REAL APADTIM,CPADTIM,VLTTIM,CBRMTIM,ABRMTIM
COMMON/PI2TIM/DIKTIM(5),CURTIM(5),PASPTIM(5),PCOPTIM(5),PLINTIM(5)
REAL DIKTIM,CURTIM,PASPTIM,PCOPTIM,PLINTIM
COMMON/SECON/ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
LOGICAL ULVAULT,LVAULT,PIPSEC,VAULT,NOSECON
COMMON/PIPCON/DIKE,CURB,ASPAD,COPAD,PLINER
LOGICAL DIKE,CURB,ASPAD,COPAD,PLINER
COMMON/LIN/LINER
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LOGICAL LINER
COMMON/TKCONT/CONCPAD,ASPHPAD
LOGICAL CONCPAD,ASPHPAD
COMMON/BERM/CBERM,ABERM
LOGICAL CBERM,ABERM
COMMON/RET1/TLINE(3),TVLT(3),TCPAD(3),TAPAD(3),TCBRM(3),TABRM(3),
+TDIK(5),TCUR(5),TPASP(5),TPCOP(5),TPLIN(5),TCATTIM
REAL TLINE,TVLT,TCPAD,TAPAD,TCBRM,TABRM,TDIK,TCUR,TPASP,TPCOP,
+TPLIN,TCATTIM
COMMON/RET2/TVAULT,TLINER,TCONPAD,TASPPAD,TCBERM,TABERM,TDIKE,
+TCURB,TASPAD,TCOPAD,TPLINER,TNOSEC,TPIPSEC,TLVAULT,TULVALT,
+TCATST,TPICATH
LOGICAL TVAULT,TLINER,TCONPAD,TASPPAD,TCBERM,TABERM,TDIKE,TCURB,
+TASPAD,TCOPAD,TPLINER,TNOSEC,TPIPSEC,TLVAULT,TULVALT,
+TCATST,TPICATH
DO 29292 L=1,NPI
IF(RETROFT)THEN
 IF(L.LE.NTK)THEN
    LINETIM(L)=TLINE(L)
    VLTTIM(L)=TVLT(L)
    CPADTIM(L)=TCPAD(L)
    APADTIM(L)=TAPAD(L)
    CBRMTIM(L)=TCBRM(L)
    ABRMTIM(L)=TABRM(L)
 ENDIF
 DIKTIM(L)=TDIK(L)
 CURTIM(L)=TCUR(L)
 PASPTIM(L)=TPASP(L)
 PCOPTIM(L)=TPCOP(L)
 PLINTIM(L)=TPLIN(L)
ENDIF
29292 CONTINUE
DO 3654 L=1,NPI
    PIPCONT(L)=0
    NPICONT(L)=0
    IF(.NOT.TPIPSEC)PIPCONT(L)=1
    IF(L.LE.NTK)THEN
UGCONT(L)=1
AGCONT(L)=0
IF(TNOSEC)  THEN
     AGCONT(L)=1
       UGCONT(L)=1
 ENDIF
NUGCONT(L)=1
NAGCONT(L)=0
    ENDIF
3654 CONTINUE
NOSECON=TNOSEC
PIPSEC=TPIPSEC
VAULT=TVAULT
ULVAULT=TULVALT
LVAULT=TLVAULT
LINER=TLINER
CONCPAD=TCONPAD
ASPHPAD=TASPPAD
CBERM=TCBERM
ABERM=TABERM
```

```
65800 DIKE=TDIKE
65805 CURB=TCURB
65810 ASPAD=TASPAD
65815 COPAD=TCOPAD
65820 PLINER=TPLINER
65825 CATSTEL=TCATST
65830 PICATH=TPICATH
65835 CATTIM=TCATTIM
65840 RETURN
65845 END
```

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11.03.04.         SRU CHARGE=     5.244UNTS.
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